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The Seventieth Anniversary of Professor Joel Stebbins and of the Washburn Observatory

By JESSE L. GREENSTEIN

It has been my good fortune to be secretary of the Midwest Group of astronomers for several years. The Group, the Madison Astronomical Society, the staffs of the Washburn, Dearborn, and Yerkes Observatories all joined in celebration, on April 7, 1948, of the seventieth anniversary of the Washburn Observatory, and of the seventieth year of Professor Stebbins. Professor Stebbins has been a good friend and scientific counsellor for many years; astronomers and amateurs alike have enjoyed his wise humor and deep scientific insight. On the occa-

DR. JOEL STEBBINS

sion of his approaching retirement from the directorship of the Washburn Observatory of the University of Wisconsin, the Midwest Group held a scientific meeting at Madison and joined the Madison Astronomical Society at a dinner in honor of Dr. and Mrs. Stebbins. I have had the pleasant task of collecting the after-dinner talks for publication in the hope that they will give to the Stebbins' many friends at least part of our enjoyment of the occasion.

The papers given at the scientific session were:

A. E. Whitford, Washburn Observatory, "The Reddening of Extragalactic Nebulae"

H. C. van de Hulst, Yerkes Observatory, "Space-Reddening and its Theoretical Interpretation"

W. A. Hiltner, Yerkes Observatory, "Photoelectric Photometry at the Yerkes and McDonald Observatories"

R. R. McMath and L. Goldberg, McMath-Hulbert and University of Michigan Observatories, "New Advances in the Study of the Far Infrared Spectrum of the Sun"

G. P. Kuiper, Yerkes Observatory, "Spectral Studies of the Planets"

The program was particularly relevant in that it showed the recent enormous progress in the technique of the use of photo-multiplier tubes and the photo-conductive cell. Only a few high-lights of the papers can be mentioned. Some years ago photoelectric observations were limited to naked-eye stars; improvements of technique have permitted Stebbins and Whitford to measure the reddening of distant extragalactic nebulae down to 18^m. They have found an unexplained reddening; when a full interpretation of this reddening is made it may require a completely new picture of the size and total mass of the expanding universe. Whitford showed how the reddening increases with the velocity of recession of the nebula. It has not yet been decided whether the reddening is connected with the theory of relativity, or with the existence of dust and gas in extragalactic space. If the latter hypothesis is accepted the dust apparently outweighs the stars throughout the universe. The photoelectric observations of space reddening in our own Galaxy have been used by van de Hulst to obtain information on the numbers of small particles of different size, and of the total density of the interstellar dust. Hiltner described the use of the photomultiplier tube in stellar photometry at Yerkes Observatory and McDonald Obervatory, and also for the measurement and recording at the telescope of the spectrum of a star directly on an intensity scale. It is probable that the photoelectric recording of spectra will be used to obtain line intensities in brighter stars, and to supplant the photographic techniques.

The photoconductive cell (lead sulphide) developed by R. J. Cashman of Northwestern University has also had applications in the direct recording of the infrared spectrum of the sun at the McMath-Hulbert

Observatory. Goldberg described some of the problems of detailed line identification. The resolution used is higher than that used even in laboratory spectrometers. Many new lines and bands were found in the solar spectrum and in that of the earth's atmosphere. It is hoped that a complete infrared atlas of the solar spectrum will eventually be published. At the other extreme, low-resolution infrared spectra of the planets were discussed by Kuiper. He has recently found that the polar cap of Mars is ice or snow and that there is probably some water on the surface and in the atmosphere of Mars. Ice crystals may account for the hazy character of the Martian atmosphere in violet light. Kuiper found indications that the particles making up the rings of Saturn may also be covered with ice.

At the end of the scientific session, Dr. W. A. Hiltner of the Yerkes Observatory was elected secretary of the Midwest Group. Will all astronomers and teachers of astronomers who would be interested in attending future meetings please write to him so that they may receive notices?

The dinner in honor of Professor Stebbins was arranged by Dr. C. M. Huffer of the Washburn Observatory who acted as toastmaster and introduced the various speakers. His informal remarks, and those of Professor Stebbins, would be the highlights of this report; however, I must limit myself to presenting the formal addresses in honor of Profesor Stebbins.

Address of Welcome

President E. B. Fred
University of Wisconsin

I am happy to have this opportunity to welcome this distinguished group of scientists and friends of science to the campus of the University of Wisconsin. We are glad to have you with us and we hope that your visit will be a pleasant one.

I am particularly pleased to have this opportunity to join in the tribute to Professor Stebbins. In his 26 years of service as director of Washburn Observatory and professor of Astronomy, Professor Stebbins has contributed much to the advancement of human knowledge. The University is proud of the important developments which have characterized the work of the Washburn Observatory under his skillful direction.

These contributions are all the more praiseworthy when it is realized that Professor Stebbins and his colleagues have worked under many difficulties. He is to be congratulated on his outstanding record.

It is my hope that it will be possible for us to maintain the fine record which Professor Stebbins has established in Astronomy in the University of Wisconsin. This is the best way I know of expressing to him our appreciation of his splendid service.

Astronomy Before 1878

Robert H. Baker
University of Illinois

Over almost any interval of modern times we can notice noteworthy advances in observational astronomy—advances which proceed geometrically so that they become more conspicuous as the interval is later. Looking back from the present time to 1878, the year of the founding of Washburn Observatory and of the birth of its distinguished director, we view a succession of forward steps to which the astronomers of this observatory have made significant contributions.

Similarly a speaker at a dinner here in 1878, perhaps in celebration of the completion of Washburn Observatory, might well have referred with pride to the accomplishments during a comparable interval, say, since the beginning of that century. He would surely have noted the increased knowledge of the details of the planetary system. He would have spoken of the discovery of Neptune in 1846, which seemed to complete the roster of the larger planets. He would have mentioned how the finding of Ceres in 1801 had opened a wide field for further discoveries of asteroids and for achievements in celestial mechanics. He might have enumerated the satellites which had become known in that interval, giving particular attention to the two satellites of Mars detected only a year before, just as we now view with special interest the recent discovery of the fifth satellite of Uranus.

The speaker at the dinner in 1878 would doubtless have remarked on the widening horizon of inquiry. He would have pointed out how astronomers were looking more often beyond the region of the planets to survey the star fields. Progress in solving the great problems of structure and evolution had been slow, to be sure. Not much had as yet been established in support of the intriguing speculations that the Milky Way represents an isolated system—that hazy spots in the heavens are other Milky Ways—that the stars emerge from nebulous stuff.

Yet important beginnings had been made in sidereal astronomy. Star clusters and nebulae had been listed and studied. Double stars had been discovered in great numbers and some had proved to be physical systems which by the manner of their mutual revolutions had given additional support to the universality of Newton's law. Even the minute parallaxes of a few stars had finally been observed.

The speaker of 70 years ago would very likely have emphasized the importance of the increased facilities for observation since the turn of that century. Large refracting telescopes, beginning with the optical achievements of Fraunhofer, had grown to more than 2 feet in diameter. High in the list in order of size and excellence was the new telescope at Madison, whose work was about to begin. Along with the increasing power of the telescope two auxiliaries had appeared which

might have seemed to promise great improvement in its effectiveness. These were the spectroscope and the photographic plate.

As early as 1814 Fraunhofer had detected and mapped dark lines in the solar spectrum. Nine years later he had noticed corresponding patterns in the spectra of stars and had made the prophetic observation that the patterns increase in complexity with increasing redness of the stars. At length Kirchhoff had established the significance of the spectral lines and so had prepared the way for studies of celestial chemistry and physics.

Celestial photography had been inaugurated and had made noteworthy progress in the half century preceding 1878. There was Draper's picture of the moon taken as early as 1840. The first daguerreotype of the sun had been made in 1845. Bond in 1850 had succeeded in getting on his plate the image of as faint an object as a star—one of the brightest stars, to be sure. And recently, in 1876, the dry plate had begun to replace the awkward procedures of the pioneers.

These developments would surely have been mentioned by the speaker in 1878 in reviewing the advances in astronomy since the beginning of the century. Had he been a sort of Drew Pearson he might have predicted spectacular progress during the next 70 years with further improvements in the telescope, spectroscope, and photographic plate. He would not have imagined the contributions of such apparatus as the thermocouple and the lead sulphide cell. He would scarcely have pictured an astronomer with the photocell measuring the colors of stars, clusters, and galaxies or exploring regions of the Milky Way invisible to the eye.

Observational astronomy in 1878 still operated chiefly with the eye at the telescope. But the photographic plate and other devices would presently replace the eye as the principal receiving agent in the night's operations. Larger telescopes would be set up in more favorable sites. Astronomers in increasing numbers, both professional and amateur, would be available to promote and evaluate the observations.

The Scientific Work of Professor Joel Stebbins

Otto Struve
Yerkes and McDonald Observatories

It was in the summer of 1913 that I heard the name of Stebbins for the first time. As a high school student I had made a trip to Germany in order to see what the professional astronomers in foreign countries were like. As a visitor I attended the meeting of the Astronomische Gesellschaft at Hamburg, an occasion which was marked by the presentation of a paper by Professor Hans Rosenberg and his assistant, Meyer, who had, for the first time, employed a photoelectric cell of the conventional type at the end of a telescope and had found that with an aperture of 12 inches they could measure the brightnesses of stars as faint as the sixth magnitude, with a probable error of the order of

0.003 mag. In the discussion that took place afterwards, Professor Stebbins congratulated the authors upon their results and briefly described his own experiments with a selenium photometer at the University of Illinois in Urbana. The work of Stebbins with the selenium photometer had created an enormous impression in Europe. Rosenberg and Guthnick who had experimented at about the same time were thoroughly aware of the skill of the American astronomers and I seem to recall that Professor Guthnick spoke in particularly glowing terms of the power of American observational astronomy.

It is appropriate at this occasion to dwell upon the fact that Professor Stebbins' first astronomical work was done at the Washburn Observatory where he spent a year as a graduate student under Professor Comstock. His first published paper, in collaboration with Comstock, was devoted to the determination of the brightness of the remarkable nova in Perseus of 1901 which has furnished some of the most valuable information we possess on stellar explosions. It is significant that Stebbins' early work was already devoted to stellar photometry, a branch of astrophysics which he later made his own and to which he has contributed the greater part of his energy. Stebbins has told us how he was almost persuaded to come to the Yerkes Observatory as a graduate student and work under Hale towards his Ph.D. degree. His first contact with Yerkes, indirect as it was, occurred at the time of the dedication of the Yerkes Observatory. He met on a train his Nebraska teacher who was then headed for Williams Bay in order to attend the meeting of astronomers in October, 1897. Stebbins' decision not to come to Yerkes but to go to the Lick Observatory has been responsible for his later close association with the west-coast observatories.

Under Campbell on Mount Hamilton he was drawn into the orbit of stellar spectroscopy and his Ph.D. thesis was devoted to an exhaustive study of the spectrum of Mira Ceti which he observed with a single-prism spectrograph from June, 1902, until January, 1903. During this period the star faded in brightness from magnitude 3.8 to magnitude 9.0. This work was instigated by Campbell who had made an earlier investigation of Mira Ceti and who had appreciated the remarkable variations in the intensities of the bright lines and other features which were present in its spectrum. Aside from Campbell's short note in the *Astrophysical Journal* for 1899 all that was then known about the spectrum of Mira Ceti was contained in two papers, one by H. C. Vogel and the other by W. Sidgreaves. Stebbins' paper in the *Bulletins of the Lick Observatory* for 1903 remained the principal source of information concerning the spectra of long-period variable stars until it was surpassed not very many years ago by an exhaustive study carried out at Mount Wilson by A. H. Joy.

The other day when I was glancing through the paper by Stebbins, I was struck by his statement that measurements of the absorption

lines on his Lick Observatory plates had shown no indication of change in radial velocity. This statement interested me because I knew that Joy had published a velocity curve which in shape and in phase closely resembled the light curve of Mira Ceti. I was rather astonished to find this discrepancy because I had become accustomed through many years of experience in utilizing Dr. Stebbins' measurements that his conclusions had an extraordinary degree of reliability. Was it possible then that I had discovered a real mistake in Stebbins' first important work? A glance at Joy's velocity curve showed that a change of about 10 km/sec normally took place between the time of maximum brightness and the time of minimum brightness, the velocity at the former phase being larger than at the latter. I then examined more thoroughly the results of Stebbins' work. He had measured five good spectrograms between July 6 and August 25, 1902. After that date, the variable was too faint for accurate measurement. During this interval of about a month and a half the radial velocity actually changed by about 5 km/sec from larger to smaller values. During this same interval of time the brightness changed from about magnitude 4 to magnitude 7 or roughly half the total range in brightness. It is quite clear that with an admirable sense of caution Stebbins had under-rated the precision of his own work and that the variation in radial velocity which is so well known at the present time was actually recorded in his results though it was not at the time acknowledged as a real phenomenon.

After Stebbins had been awarded the Ph.D. degree by the University of California and had successfully passed through the rigorous school of celestial mechanics under Leuschner he became director of the University Observatory at Urbana, Illinois, and soon engaged in the first experiments to utilize electrical methods for the measurement of stellar brightness. I find in an article which he presented before the American Astronomical Society in 1908, the following statement which gives us an appreciation of the fabulous increase in sensitivity and in precision which has been the result of development of photometric technique by Stebbins and his pupils.

"This paper presents the results of experiments on the use of selenium in stellar photometry. It is well known that the crystalline form of selenium decreases its electrical resistance when exposed to light. The method is to cast an extra-focal image of a star upon a selenium surface, and note the effect by means of a galvanometer. Using a twelve-inch telescope, it has been possible to measure first and second magnitude stars with about the same accuracy that is obtained in visual methods. Tests with brighter artificial lights give a probable error of less than one per cent for a single measurement.

"In the course of a year the sensibility of the apparatus has been increased one hundred fold, and it is hoped that further improvements in the elimination of disturbing factors will produce extremely accurate results."

During the next few years Stebbins greatly improved the precision of the selenium photometer and immediately applied it to the observation of important stars. An accurate light curve of Algol in 1910 revealed for the first time the existence of the secondary minimum of this eclipsing system. This secondary minimum had been sought for in vain by the visual observers and its discovery marked an important advance in the study of close double stars. Of even greater importance was Stebbins' discovery of a continuous variation in the brightness of Algol between two principal minima which in the words of the author made this star a distant relative of β Lyrae. However, while in the latter maximum brilliancy occurs half-way between any two successive minima, in Algol the maximum brightness was observed just before and immediately after the secondary minimum. It is of interest to quote Stebbins' own interpretation of the light curve:

"The most obvious explanation of the continuous variation of light between minima is that the companion keeps one face toward Algol and is brighter on that side due to radiation received from the primary. I therefore assume that the companion rotates uniformly once in the period of revolution and that it is divided into two hemispheres each uniformly intense. While this last assumption is probably far from the truth it is sufficient for the accuracy of the observations." Much later, when Stebbins was a visiting astronomer at the University of Munich under Seeliger he returned to the theoretical treatment of what we now describe as the reflection effect of eclipsing variables. His discussion of this phenomenon appeared in the *Seeliger Festschrift.*

Some of the most important results of this phase of Stebbins' work were devoted to eclipsing variables. He was one of the first to recognize that ordinary spectroscopic binaries having a large range in radial velocity were likely objects to show eclipses of small range. The first two spectroscopic binaries which he examined proved to be variable. Beta Aurigae was found to have two equal eclipses of less than 0.1 mag. in depth, while Delta Orionis, a famous B1 spectroscopic binary, has eclipses of slightly more than 0.1 mag. in depth. With the selenium photometer and later with the photoelectric cell Stebbins has systematically investigated the brightnesses of nearly all accessible spectroscopic binaries listed in the Lick catalogues of Campbell and Moore. This work ranks among the greatest contributions made to double star astronomy. The results were summarized in Volume 15 of the *Publications of the Washburn Observatory,* of which he had became the director in 1922. They are being constantly consulted by workers in related fields. It is a pleasure to record that Dr. C. M. Huffer has in recent years continued this phase of Stebbins' investigations, and has added many new eclipsing variables to those found earlier by Stebbins himself. The importance of this work consists not only in the knowledge it provides concerning the physical characteristics of important double stars—a knowledge which is essential for the study of the mass-lumin-

osity relation—but it has also great statistical interest and furnishes a mine of information that has been only partly uncovered. Fifteen or twenty years ago Stebbins rightly claimed that nearly all those spectroscopic binaries which he expected to show eclipses actually showed them. We are now more concerned with the fact that he also discovered eclipses in many systems which he had not expected to have inclinations in the vicinity of 90°. These remarkable "unexpected" variables are in many respects more interesting and significant than those which behaved in accordance with our expectations.

I am afraid that I am going too far into the field of spectroscopic binaries, my excuse for doing so being my own extensive interest in these results by Mr. Stebbins. I could easily spend the rest of the evening summarizing for you the vast number of discoveries of new and important eclipsing systems and the even more important interpretations which we owe to him. His unsurpassed precision of photometric measurement made it necessary to develop the theory of eclipsing stars—a fundamental contribution to astronomy by Professor H. N. Russell. Incidentally, it should be mentioned that Stebbins' own masterly discussion of the orbit of Algol appeared three years before the work of Russell was published in the *Astrophysical Journal*. The discovery of variable stars of the ellipsoidal type, without eclipses, formed another of the notable contributions in this period of Mr. Stebbins' investigations.

His long series of observations of eclipsing variables was followed by a survey of 190 stars of class M. Approximately one-third of them were found to be variable but in the majority of cases the range was small and the character of the variation non-periodic. As a result of this work we now know that probably no giant or super-giant M-type star is entirely constant in brightness. These stars are undoubtedly intrinsic variables whose changes in brightness are caused by physical processes in their atmospheres.

Another type of variable star which received careful attention was the Cepheid variable and especially the pseudo-Cepheid variable of the Beta Cephei type. Beta Cephei itself was discovered to be a variable star by Guthnick at Berlin, but Stebbins obtained a long series of measurements of the magnitude of another important representative of this class, namely 12 Lacertae. The nature of these stars is still obscure. Stebbins pointed out that the light curves are variable in shape and amplitude. Some, like Beta Cephei and 12 Lacertae, have constant periods and well-defined, though variable, velocity curves, while others like Beta Canis Majoris show only periodic changes in the radial velocities and profiles of the absorption lines, but little or no variation in light. In some respects these stars resemble the cluster-type Cepheids and they are usually regarded as members of the Delta Cephei group of intrinsic variables. However, it is not easy to understand how the rapid variations in the light curve can be due to pulsation. Stebbins

concluded long ago that from the point of view of a photometric observer these stars were highly disappointing. The variations, often occurring in relatively short periods of the order of one-fourth day, were so erratic in shape as to defy any attempt at a physical interpretation. He has therefore in recent years avoided this class of variables, expecting, no doubt, that some important advance in another field would help to clarify the situation. Last December we were all electrified when Stebbins' youngest pupil, Mr. Olin Eggen, announced changes in the brightness of Beta Cephei which occurred within intervals of a few seconds. If these observations should be substantiated by Eggen's later work they would bring about a revolution of astronomical thought comparable to that which took place when Pickering announced that a double star could have a period of only 4 days.

About 20 years ago Stebbins embarked upon the ambitious project of determining the colors of a vast number of early B-type stars. After many years of uncertainty astronomers had finally accepted the view that interstellar space was not empty but contained large quantities of finely divided dust or smoke which not only dimmed the light of the more distant stars but also made it appear reddish in color. Russell had pointed out that some of the most highly reddened B-type stars in Perseus were involved in obscuring matter easily visible on the Milky Way photographs of Barnard and Wolf. Bottlinger had made a first attempt at measuring the brightnesses of a small group of B-type stars in two different regions of the spectrum, and these observations yielded fairly convincing evidence in favor of a general selective absorption in interstellar space. The work of Stebbins, who was assisted by C. M. Huffer and later by Whitford, produced a catalogue of the colors of all accessible B-type stars and this material has been used by nearly all living astronomers in one way or another. It not only confirmed the existence of interstellar absorption but enabled us to determine its amount and more recently even the wave-length dependence of the absorption coefficient. Our first thoughts concerning this dependence were in terms of the famous λ^{-4} law of Lord Rayleigh. Stebbins' photoelectric measures established beyond doubt that the Rayleigh type of absorption was not effective and that a law involving the inverse first power of the wave length more nearly represented his observations. His greatest contribution in this field, and perhaps of his entire career, was the recognition that even the λ^{-1} relation is not entirely correct and that the true form of the absorption coefficient is a more complicated function of the wave length. Whitford's recent extension of the color measurements into the extreme infrared part of the spectrum by means of Cashman's lead sulphide cell has brought about a still further extension of our knowledge of the interstellar absorption coefficient.

I need not remind this audience that Morgan, Greenstein, van de Hulst, and many others at the Yerkes Observatory have constantly made use of the Madison and Mt. Wilson color measurements. But

exciting as they have proved to be I believe the most mysterious result of this group of Stebbins' investigations was the discovery of a peculiar form of the absorption coefficient which operates in the region of the great nebula in Orion and causes the stars of the Trapezium to have a somewhat unusual distribution of light in their continuous spectra. This result is closely connected with Baade's photographic observations of these stars and with his most recent results concerning the variability of the background field of faint stars in the region of the nebula.

Stebbins' latest investigations have been concerned with the brightnesses and colors of the extra-galactic nebulae. This work is of so recent an origin that everyone in this audience will remember it from his own papers at various neighborhood meetings and at meetings of the American Astronomical Society. His paper last December in Columbus so greatly impressed the audience that Chandrasekhar, who conducted an informal poll after the meeting, found unanimous agreement among astronomers in awarding it first place among the contributions to the Society.

In this very brief account I have only been able to touch upon some of the high lights of Mr. Stebbins' investigations. I have passed by many other important topics, such as his and Whitford's joint work on the infrared radiation of the center of the galaxy; his recent six-color observations of several bright Cepheid variables which resulted in the discovery of a lag in time of the phase of maximum brightness; his photoelectric observations of the surrounding regions of the Andomeda Nebula which paralleled the photographic work of Shapley; and many others. At the Yerkes Observatory we owe to him the inauguration of our first photoelectric program when he was a visiting professor and built for us an instrument with a Kunz cell. He also provided the inspiration to Dr. C. T. Elvey in the latter's photoelectric work at Yerkes and McDonald.

In a lecture on February 17, 1941, before the Astronomical Society of the Pacific he most vividly described the sensitivity of the photoelectric cell then in his possession:

"After telling visitors for many years that we would measure a candle a mile away without a telescope, we decided to make good by placing a real candle a real mile away and measuring the effect on the photocell. Accordingly, a candle was placed on Picnic Point, across Lake Mendota some 5200 feet from the Observatory at Madison, the photometer was taken off the telescope and properly pointed, and on signal an assistant on the Point occulted or cleared the candle, while the observer at the galvanometer recorded the resulting deflections. The burning candle gave deflections of 170 mm, correct to less than 1 mm, so the test was too easy. Next the light was reduced to 1/50 candle, equivalent to a candle at 7 miles, and the deflections were more than 3 mm. It was estimated that the limit of detection would have been a candle at 30 miles, and since the photocell was 1 inch in diameter this

sensitivity corresponds to a candle at 3000 miles with the 100-inch telescope, neglecting, of course, any atmospheric absorption after the first mile. As a candle can be seen with the eye at a distance of only 5 or 6 miles, it would appear that the photocell is better than the eye, but the diameter of the cell in the experiment was 1 inch compared with a maximum of one-third inch for the pupil of the eye in the dark. Reduced to the same aperture, the calculated sensitivities of the cell and the eye are about the same.

"A similar comparison was made between the cell and a photographic plate. In a series of exposures on Sirius with a 1-inch lens it was found that 1/25 second gave a threshold image but 1/50 second gave no image at all. With a photocell and short-period galvanometer it was easy to record deflections from exposures of 1/50 second on the same star. Thus for a given time-interval the cell is twice as sensitive as the plate, but there is the cumulative effect of long exposure on a photograph which cannot be duplicated by a cell."

Since 1941 the photomultiplier tubes, the various automatic recorders and the red-sensitive cells have produced still further gains in sensitivity, precision, and general usefulness of the electronic method of measurement. The other day when Professor Luyten saw Dr. Hiltner's new installation at the Yerkes Observatory he was moved to comment that the days of photographic photometry for single stars are just about over. Given the equipment and an experienced electronics operator the brightness of a star can be measured faster, much more accurately and to a fainter limiting magnitude than on a plate. The great usefulness of the latter consists mainly in the size of the field which it can cover. All this even though, for the present, electronics experts are still rare visitors in astronomical gatherings!

Even in stellar spectroscopy the electronic methods are threatening to displace those based upon the good old photographic procedure. When that happens some of us will have to learn new tricks and when we do we shall remember that we owe this intrusion into our smug complacency very largely to our guest of honor.

No other astronomer has had the exceptional good luck—and luck is always willing to help when skill and perseverance are present—to see his method increase in sensitivity from limiting magnitude 6 to 21 or 22, or by a factor of more than a million, and at the same time increase the precision of measurement from a probable error of the order of $\pm$ 0.02 mag. to less than $\pm$ 0.001 mag. or by a factor of more than 20.

Stebbins' work was early recognized by his colleagues. He received the Rumford Medal of the American Academy of Arts and Sciences in Boston in 1914 and the Draper Medal of the National Academy of Sciences in 1915. I believe there have been few, if any, astronomers who received both of these distinctions at such an early age: 36 and 37 years, respectively. After Stebbins had obtained the Bruce Medal

he had about exhausted the formal distinctions open to astronomers in this country. Hence, some years ago when he returned to the scene of his early activities on the Berkeley campus in order to conduct a meeting of the American Astronomical Society, his friends and associates could think of no other way to express their admiration for him than through the presentation of a large chocolate medal wrapped in gold foil and displaying a picture of the Golden Gate Bridge. Mrs. C. D. Shane, the wife of the present director of the Lick Observatory, produced an appropriate box and Professor Tracy Crawford of the Astronomy Department of the University of California and one of Stebbins' early friends and associates in his graduate days, made the speech of award, highlighting his "heroic devotion" to the Astronomical Society whose meetings he had attended without interruption for a greater number of years than any other member.

Our small group of Neighborhood Astronomers has no medal to bestow, but I want to return to Mr. Stebbins the old Panama-Pacific International Exposition Medal which he had received for the American Astronomical Society and which he had used as a paper weight from 1915 until 1947—when he felt impelled to return it to the Society for the Fiftieth Anniversary celebration at the Yerkes Observatory, last September. To mark the present occasion we have added the date of April 7, 1948, on the face of this medal and we have also cleaned it up and made it look more like the piece of gold we wish it were. I am sure the Council of the Astronomical Society would approve this action and would want Mr. Stebbins to continue using it as paper weight in his new office on Mount Hamilton.

Remarks by Jesse L. Greenstein

Yerkes Observatory

Before I read a formal letter from the members of the staff and the students of the Yerkes Observatory, I would like to add a few remarks of my own. As one of the younger generation of astronomers, my work has been for a long time related to and dependent on that of Dr. Stebbins and his collaborators. It has been my good fortune that if I were interested in a problem, I always had someone to fall back on, when it came to settling the question accurately and finally. For example, I thought it was important as a student to determine how interstellar absorption depended on wave length. It was obvious that an important means of estimating the total absorption of light in space could be found if this law of interstellar absorption were accurately determined. My own thesis, at Harvard, was on that subject; the problem was merely begun. However, I was lucky—Dr. Stebbins became interested in getting the *true* law of interstellar absorption. Now he has increased the accuracy ten-fold and multiplied the range of wave length by six. Detailed theoretical interpretation is now justified by high observational accuracy. Another example is the color of extra-

galactic nebulae. When I came to Yerkes I measured one nebula, the Andromeda Nebula, and found a rather suggestive feature, the considerable redness, the interpretation of which was not completely clear. Now, Stebbins has gone fifteen magnitudes fainter, and those who heard Dr. Whitford's talk this afternoon realize that a new and fundamental problem has been opened up by the ingenuity and perseverance of the Washburn observers. I could go on recounting other occasions. When, in astrophysical problems, one needed the temperature of a strange type of star, all one needed to do was to interest Stebbins in the problem, and the color-temperature was soon forthcoming. I know I shall miss the daily contacts with him, and with his willingness and imagination, which have contributed so much to the growth of modern astronomy, and to the personal pleasure of being an astronomer.

I will now read a letter, signed by present and former members of the Yerkes staff and by our students, who have joined to honor Dr. and Mrs. Stebbins.

"Dear Professor Stebbins:

During the past quarter of a century you have been our nearest astronomical neighbor. Your brilliant research has given us inspiration and courage in our own investigations; it has profoundly affected astronomical thinking. We have profited extensively from your measurements and admired their superb precision. Whenever new problems arose you developed new techniques—and the new high order of accuracy you attained always suggested new problems. Your sound judgment has guided our decisions and your sparkling humor has enlivened our meetings. It is no exaggeration to say that in spite of the seventy miles which separated us you have continuously exerted a most profound influence upon the work of the astronomers of the Yerkes Observatory. If the East has a Russell and the West an Aitken and an Adams, we in the Middle West can proudly claim you as our most distinguished and most beloved colleague. We ask you to accept this token of the respect and affection of our staff and our students. We know that retirement will mean for you only a new opportunity for research in the surroundings of the Lick Observatory where you started your long astronomical career. Our most sincere wishes for complete happiness will go with you and Mrs. Stebbins."

A Letter from Dr. C. T. Elvey of the Naval Ordnance Test Section, Inyokern, California

"Gentlemen:

I am very sorry that circumstances make it impossible for me to attend this meeting in honor of Joel Stebbins on the eve of his retirement. Some 18 years ago when learning the mysteries of a photoelectric photometer from Stebbins, we younger men referred to him as 'the father of photoelectric photometry.' We are now replaced by a younger generation and would not be surprised if he were called

'grand-daddy of photoelectric photometry,' specially since his work in precision photometry reaches over a span of forty years.

His earliest works demonstrate the skill and great patience he had for precision photometric measurements. You may recall his conquering the erratic behavior of the selenium cell and applying it to the measurement of the brightness of stars and other astronomical bodies. Almost exactly 42 years ago he observed the light curve of Algol with the selenium photometer and obtained results much superior to either the visual or photographic methods. The probable error of a single observation was about 2%, and consequently, he was able to discover the secondary minimum with a depth of only 0.06 magnitude, and also, that the brightness varied continually between the minima.

During the next ten or twelve years Stebbins exploited the selenium photometer by measuring the light curves of variable stars and the moon and observing the brightness of Halley's comet. It was during this period that he made a very valuable contribution to astrophysics by demonstrating that many of the spectroscopic binaries were eclipsing variables. The spectroscopic binary Beta Aurigae was first discovered to have an eclipse with a depth slightly less than 0.08 magnitude. Furthermore, it was shown that the components were elliptical.

I do not know many of the details of the early association of Joel Stebbins and Jacob Kunz, but do know that it had a profound effect upon precision photometry. Their first collaborative effort was the application of the photoelectric cell to measuring the brightness of the corona at the total eclipse of the sun on June 8, 1918. At the same time Stebbins and Dershem applied the photoelectric principle to stellar photometry by measuring the brightness of Nova Aquilae 1918.

During the next twenty years Kunz enjoyed the reputation of being the only one who could make a photo-cell with sufficient sensitivity and a dark current small enough that it could be used for astronomical photometry. Stebbins has frequently said that to make a big telescope out of a small one, all you had to do was get a good Kunz photo-cell; and Stebbins had first choice of all the cells which were produced. Through the later years Stebbins continued making bigger and bigger telescopes out of small ones by improving the techniques of photoelectric photometry. He and his colleagues have made many improvements in the methods of measuring the tiny photoelectric current. I recall a few years ago his telling me that he had succeeded in making the telescope at Washburn almost as big as the 40-inch refractor at Yerkes through the use of an amplifier in the photometer.

Dr. Frost made arrangements with Stebbins some 18 years ago to design, build, and put into operation a photoelectric photometer on the 40-inch refractor. It was my good fortune to be chosen the one whom Stebbins would teach to operate it. It is with great pleasure that I recall the many hours spent in the domes at Yerkes and Washburn learning some of the skills in handling a photoelectric photometer.

Of course, there were one or two slightly unpleasant experiences, such as learning that the sodium metal, after it has absorbed moisture in drying the air, can creep into the Lindeman electrometer and exert a deleterious effect upon its internal structure.

In closing I wish to send best regards from several ex-astronomers now located in the desert lands of Southern California."

Remarks by R. R. McMath

McMath-Hulbert Observatory

Dr. Joel Stebbins is one of two or three men who greatly encouraged me during the early days of the McMath-Hulbert Observatory. I can well remember a question he asked of me when I showed our first solar motion-picture films before a meeting of the National Academy in Ann Arbor, in the early 30's. He said, "Fine stuff, McMath. Do you plan to keep on with this work, or are you going to stop after having demonstrated its possibilities?" It is possible that the foregoing remark was enough to cause me to make up my mind. One can never tell, and as always, hindsight is much better than foresight. A vivid recollection is his visit to the Lake Angelus Observatory, upon the occasion of the dedication of the new McGregor Tower Telescope and building. With his hand on my shoulder, he said, "You seem to be a good mousetrap builder, Bob, and I hope that you are able to keep the people coming to your mousetrap." It has been a great privilege to call Joel Stebbins a friend during the past fifteen or more years, and I have sought his advice on many occasions and never gone wrong by taking it. Through experience, I know that Dr. Stebbins is a grand traveling companion, and I have had many a hearty chuckle, derived from his very keen sense of humor. If I had time, I could expand these remarks indefinitely. Suffice it to say that he has been a fine critic and a source of tremendous encouragement to a man who has more or less come into astronomy "through the back door."

Remarks of A. E. Whitford

Washburn Observatory

I speak as another who came into astronomy *via* the back door, the door labeled "physics." The man who held the door open was Joel Stebbins. I was fresh from the messiness of the physics laboratory, and accustomed to its rather happy-go-lucky ways, at least as measured by observatory standards. There was much to learn about how to be an astronomer. I could not have had a better teacher.

One of the lessons was the importance of relating one's work to what has gone before, and of realizing that what one does now builds upon the previous knowledge, and that it must be performed and recorded in such a manner that it will in turn be a firm foundation for future work. On the very first day that I entered the Washburn Ob-

servatory this sense of continuity with the past was impressed on me by the high ceilings, the carved woodwork, the bearded portraits, the ticking clocks, and the rows of neatly kept record books. The indoctrination process is perhaps no better illustrated than by the reverent attitude which Dr. Stebbins taught me to have toward the little pieces of filter glass which were used for measuring the colors of stars. As more and more stars were measured through a given piece of glass, it acquired a sacred character only a little below that of the Holy Grail. Opening the box where it was kept, or installing it on the telescope, was a ceremonial rite not to be lightly undertaken.

A second lesson was the importance of maintaining a detached and philosophical attitude. One's personal feelings, enthusiasms or discouragements should not be allowed to sway one's calm judgment. One of the times when Dr. Stebbins' even-tempered way was something for which I was very thankful was the occasional night when the apparatus did not work. My own spirits were apt to be low, for I was supposed to make it work. Dr. Stebbins was always exceedingly patient and sympathetic. But when things were going well, there were sometimes little signs. Perhaps Dr. Stebbins never knew how those who worked with him had carefully calibrated those signs. When the work was going smoothly and the data book was filling up with good observations he was very apt to begin whistling "La Golondrina." There was another sign reserved for the very finest nights when the apparatus was performing particularly well, or when an especially desired or difficult observation was proceeding according to plan; then the quiet of the dark and lonely dome would be broken by Dr. Stebbins' bursting out with the song "Ah, Sweet Mystery of Life, At Last I've Found Thee."

These reminiscences may indicate in an indirect way the personal feelings of all of us at the Washburn Observatory who have worked with Dr. Stebbins. We who have had daily contact with him know how much his wisdom, guidance, and encouragement has meant. We are the ones who realize, perhaps better than anyone else in the University community, how much his leadership is responsible for making the name of the Washburn Observatory an honored name. And we are also the ones who are most keenly aware of the tremendous hole that will be left when he retires.

And so we want to join with the others who are honoring Dr. Stebbins on this occasion, and to say that our admiration, our gratitude, and our affection go with him as he continues his work at another place next year. We want to assure him that whenever he comes back to Madison, a very warm welcome will be waiting for him at the Washburn Observatory.

The Planetary Theory of Laplace

By A. PANNEKOEK

I

The main problem occupying astronomers and theorists in the 18th century was this, whether Newton's law of gravitation would be able to explain the motions of the heavenly bodies. Newton had derived the law, so extremely simple in its mathematical form, from Kepler's laws of the planetary orbits; and he had confirmed its validity by explaining in this way the precession of the equinoxes, the tides, and some of the most notable irregularities of the moon. But it implied that Kepler's laws could not be strictly true; the mutual attraction of the planets produces perturbations of their regular courses, some of which had already become evident through the increasing accuracy of the observations. So the problem was to give an explanation of these irregularities by means of theory. Or, in a more general way, theoretically to derive with the utmost precision the motions of the planets and the moon, and to compare them with the observational results. A group of the most brilliant theorists came forward, mostly in France, such as Clairaut, Euler, d'Alembert, and later Lagrange and Laplace, who set themselves this task. While gradually the methods of computation developed under their hands, the explanation of such riddles as the secular acceleration of the moon and the gradual opposite change of the periods of revolution of Jupiter and Saturn, for a long time baffled the most astute mathematicians; and only in the later part of the century Laplace succeeded in giving a solution.

All this progress was made possible only owing to the introduction of a new form of mathematical treatment. Algebra, calculus, had to replace geometry. It was well known how geometrical problems which by their complexity demanded the keenest insight and perspicacity, could be solved in a simple way, by downright computation, when transformed into algebra by the methods of analytical geometry. The still more difficult problems of mechanics could be solved by calculus only. Celestial mechanics, the science of the motions of the celestial bodies on the basis of Newton's law of gravitation, could develop in the 18th century only by abandoning Newton's geometrical treatment and converting it into an algebraic computation. This was the work of the 18th century scientists already named. The final result of their work at the end of the century was laid down in Laplace's *Traité de Mécanique Céleste* (Treatise of Celestial Mechanics).

In his introductory "Plan of the Work" he writes: "Newton published, towards the end of the past century, the discovery of the universal gravitation. Since that time the geometers have succeeded in

reducing to this great law of nature all known phenomena of the world system, thus giving an unexpected precision to the astronomical theories and tables. . . Astronomy, considered in its most general way, is a large problem of mechanics, in which the elements of the motions appear as the arbitrary constants; its solution at the same time depends on the exactness of the observations and on the perfection of the analysis, and it is of the highest importance to remove all empiricism and to take from observation only the indispensable data. . ." As a curious remembrance of the time of the publication (1799) the last sentence of the preface may be quoted: "I will adopt here the decimal division of the right angle and of the day, and all linear measures will be expressed in the *mètre*, determined from the arc of the terrestrial meridian between Dunkirk and Barcelona." Whereas the length unit with its decimal system has maintained itself in science, the decimal division of angles and times has not succeeded in coming into use; thus expressed in his seconds of time of 0.864 of our seconds, and his seconds of arc of 0".324 we meet here with the uncommon sight of a gravity acceleration of 3.65548 *mètres* and of a lunar parallax of 10536".

II

From the general analytical treatment of motion and equilibrium, and of systems of bodies attracting one another, which Laplace gives in the first part of his work, we take here the simple formulas needed for the special cases of planetary motions. Analytical treatment of phenomena in space means use of coordinates, rectangular xyz, or other ones. Newton's law then says that the acceleration, the second differential quotient of a coordinate is given by the force in that direction. Laplace introduces here the space function Q—afterwards called potential—the gradient of which in any direction is the force in that direction. Hence

$$d^2x/dt^2 = P_x = \partial Q/\partial x, \text{ similarly for } y \text{ and } z.$$

With the sun (mass M) as the only attracting body we have for the planet at distance r

$$P = -M/r^2;\ Q = M/r;\ d^2x/dt^2 = -M/r^3 \cdot x/r, \text{ similarly for } y \text{ and } z.$$

First the problem of two bodies, the simple elliptic motion of a planet, is discussed. Whereas Newton solved in a rigid and elegant way the problem, how to derive the law of attraction from the given elliptic motion, he did not demonstrate explicitly the more difficult problem that in the case of the inverse square law the orbit needs must be a conic section. Laplace, on the contrary, through the analytical method easily solves the latter problem by a double integration; this demonstration has since found its way into every textbook.

In the case of more attracting bodies their forces have to be added together. Here the usefulness of the potential function Q presents itself; forces must be combined geometrically because (being vectors)

they have different directions, but the space functions of which they are the gradients are numerical values (scalars) and can be added algebraically. Thus for each disturbing planet a term is added. Or, more precisely, two terms. Because the solar mass surpasses all the planetary masses by factors of more than 1000, the effect of the planetary attractions appears as small secondary corrections to the primary regular orbit. It is these corrections, the perturbations, for which equations are formed, and the additional disturbing forces that produce them are the gradients of an additional potential function, called the "disturbing function" R. Since the resulting motion is referred to the sun as the centre of coordinates, the effect of the disturbing body, the change in place relative to the sun, is determined by what its attraction upon the planet is different from its attraction upon the sun; hence the "direct" term expressing the attraction of the planet, has to be diminished by an "indirect" term expressing the attraction of the sun by the body. Thus for one disturbing body, with mass m', distance r' from the sun and ρ from the disturbed planet, and with θ the angle between the radii r and r',

$$d^2x/dt^2 = -Mx/r^3 + \partial R/\partial x, \text{ etc. } R = m'/\rho - m'rr' \cos\theta/r'^3.$$

In the case of more disturbing planets for each of them two analogous terms appear in R.

Laplace transforms these equations for the rectangular coordinates into equations for the polar cordinates: the distance, the longitude, and the deviation perpendicular to the plane of the orbit. These equations have to be integrated.

III

The differential equations, having the required unknown coordinates themselves contained in the expressions of the forces and of the disturbing function, are far too complicated to be solvable in a direct way. They must be solved by successive approximations; first the undisturbed values of the coordinates are substituted in the expressions of the forces, and by thus integrating the equations the resulting changes of the coordinates are found. They are of the order of the disturbing masses (the largest of which is 1/1047) and are called perturbations of the first order. Then these changes should be introduced in the forces, giving small deviations in the equations and producing deviations in the first-found results; these are the perturbations of the second order with respect to the masses. Because they are, at most, a thousand times smaller than the first-order results, they usually can be neglected; only in exceptional cases it is necessary to give attention to second-order terms.

But the equations for the first-order perturbations also are too complicated to be solved in a direct way. The method developed by 18th century analysis consists in decomposing each function occurring in the expressions into an infinite series of goniometric functions, which

each of them is easily tractable. In the undisturbed elliptic motion the radius as well as the anomaly are periodic functions which can be expressed in a series of terms containing sines and cosines of multiples of angles increasing uniformly with the time, at a rate given by the mean angular motion n of the planet. With ϵ the longitude at $t=0$ and π the longitude of perihelion, it is multiples of the mean anomaly, the angle $nt+\epsilon-\pi$, which appear in all the expressions for radius and longitude. Thus

$$r/a = (1+\tfrac{1}{2}e^2) - e\,(1-\ldots)\cos(nt+\epsilon-\pi) - \tfrac{1}{2}e^2\,(1-\ldots)\cos 2(nt+\epsilon-\pi) - \text{etc.}$$

$$l = nt+\epsilon+(2e+\ldots)\sin(nt+\epsilon-\pi) + (5/4\,e^2-\ldots)\sin 2(nt+\epsilon-\pi) + \text{etc.}$$

Each coefficient contains a series of terms of powers of the eccentricity increasing by 2, and the lowest power is equal to the coefficient before the angle. Moreover the angular distance of two planets θ, that appears as the chief variable determining the variations in mutual distance and mutual disturbing force, is given, in the case of coinciding planes of the orbits by $(n'-n)\,t+\epsilon'-\epsilon$.

In what way the direct term of the disturbing function depends on this angle is indicated (for the case of Jupiter and Saturn, where the ratio of the mean distances to the sun is 0.5453) by the heavy line in Figure 1. This function has to be resolved into a series

$$1/\rho = \tfrac{1}{2}A_0 + A_1\cos\theta + A_2\cos 2\theta + A_3\cos 3\theta + \text{etc.}$$

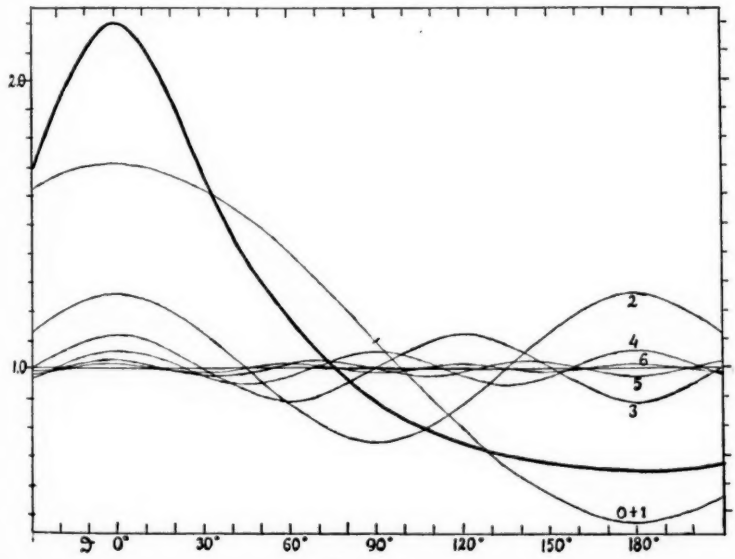

FIGURE 1
DECOMPOSITION OF THE DISTURBING FUNCTION

Introducing $a/a' = \alpha$ (always the larger radius in the denominator):

$$1/\rho = 1/\sqrt{(a^2 - 2aa' \cos\theta + a'^2)} = 1/a' \ (1 - 2\alpha \cos\theta + \alpha^2)^{-\frac{1}{2}},$$

it comes down to a development of the latter function. Laplace devised a most elegant development of the more general case where the exponent is taken $-s$ and s can have the values 1/2, 3/2, 5/2, etc. It is given in the form

$$(1 - 2\alpha \cos\theta + \alpha^2)^{-s} = \tfrac{1}{2} b_s^{(0)} + b_s^{(1)} \cos\theta + b_s^{(2)} \cos 2\theta + \text{etc.}$$

where the coefficients b are since known as "Laplace's coefficients." They are functions of the ratio α; Laplace developed them into power series, studied their properties, and indicated how only the first members have to be computed directly, whereas all the others then can be derived easily by means of their mutual relations. By means of the numerical values of all these coefficients which he gives in his 6th Book —in our case $b^{(0)} = 2.1802$ and the other b's are 0.6206, 0.2576, 0.1180, 0.0566, 0.0278, 0.0139, 0.0070, etc.—we have inserted the separate component curves into our Figure, the 2nd down to the 6th as oscillations about the line 1.0. The coefficients b for $s = 3/2$ and the derivatives with respect to α, which are needed for the case of eccentric or mutually inclined orbits, are likewise computed.

In the case of circular non-inclined orbits the disturbing function is restricted to the series in the elongation θ, where the indirect term is included in the second term with coefficient A_1. In the case of elliptical orbits the factor r/a and the difference $l - (nt + \epsilon)$ give rise to products of goniometric functions. These products are easily reduced to sums of such functions, whereby sums and differences of the arcs appear as arguments. So for instance

$$A_3 \cos 3\ (n't - nt + \epsilon' - \epsilon) \times e \cos\ (nt + \epsilon - \pi) =$$
$$\tfrac{1}{2}\ A_3\ e\ \{\cos\ (3n't - 2nt + 3\epsilon' - 2\epsilon - \pi) + \cos\ (3n't - 4nt + 3\epsilon' - 4\epsilon + \pi)\}$$

In the same way r' of the other planet gives rise to terms with the coefficient e'. When the multiplicity of nt and $n't$ (as well as of ϵ and ϵ') are different by 1 the coefficient contains e or e' in the first power; when by 2 or 3 it is of degree 2 or 3 in the eccentricities. In the same way the mutual inclination of orbits produces a number of terms having ascending powers of the inclination (more exactly: of tan $\frac{1}{2}\phi$) in the coefficients and the longitude of the node Ω in the arguments. So the disturbing function consists of a large, or rather infinite number of terms which, however, since the Laplace coefficients b rapidly decrease and the eccentricities are of the order 0.1 or smaller (Jupiter 0.048, Saturn 0.056, Mars 0.093, only Mercury 0.206), have only to be used in a limited number.

All these terms appear in the disturbing force; its irregular and complicated variation has been dissolved now into a large number of entirely regular periodic forms, sines and cosines of arcs containing the time multiplied by a certain multiple of n' and a certain multiple

of n, say $i_1n' - i_2n$. Then the changes in the coordinates are found by double integration with respect to the time. This integration, for a goniometric function, simply comes down to division of the amplitude by the square of the coefficient of t, hence by $(i_1n' - i_2n)^2$. So the perturbations in the coordinates also are found as a series of terms of the same kind.

Laplace instead of in rectangular coordinates derives the more natural perturbations in radius and longitude δr and δv, for which the disturbing force is somewhat more complicated, and the equations take a different form. He introduces the simple periodic function $u = e \cos(nt + \epsilon - \pi)$ on which in the undisturbed elliptic motion the variations in radius and in longitude or anomaly depend by means of simple relations expressible in rapidly converging series. The same relations between the disturbed u and the disturbed radius and longitude hold in the real motion; hence the differential equation for u with all the perturbation terms has to be derived and solved. This equation has the form

$$d^2u/dt^2 + n^2u = \Sigma\, p \cos(i_1n't - i_2nt + \ldots)$$

where the second member consists of all the perturbation terms as derived and mentioned above. Without these terms the solution would be a simple "free" oscillation with frequency n and arbitrary amplitude and phase [such as $e \cos(nt + \epsilon - \pi)$]; now "enforced oscillations" are added, having the periods of the additional forces, one for each term

$$u = C_1 \cos nt + C_2 \sin nt + \Sigma\, [p/\{(i_1n' - i_2n)^2 - n^2\}] \cos(i_1n't - i_2nt + \ldots)$$

From this δu consisting of the sum total Σ, the perturbations in radius and longitude δr and δv are derived and consist of analogous terms.

In this way Laplace has solved the problem, first theoretically in his 2nd Book, and then, in his 6th Book, in numerical values. In the case of Jupiter as disturbed by Saturn, *e.g.*, we find in the perturbations in longitude first a series of terms without eccentricity:

$$+81''.2 \sin\theta - 204''.4 \sin 2\theta - 16''.9 \sin 3\theta - 3''.9 \sin 4\theta \ldots - 0''.041 \sin 9\theta$$

where θ stands for $n't - nt + \epsilon' - \epsilon$ (Laplace gives 6 decimals of his smaller seconds); then 22 terms follow with the first powers of the eccentricities e or e', among which the largest are

$$-138''.4 \sin(2, 1, \pi) + 56''.6 \sin(2, 1, \pi') - 44''.4 \sin(3, 2, \pi) + 84''.9 \sin(3, 2, \pi')$$

where $(3, 2, \pi)$ means $3n't - 2nt + 3\epsilon' - 2\epsilon - \pi$; Laplace gives them down to $(7, 6, \pi)$. Then follows a series of terms of the second degree in e and e', of course not complete. "The large number of inequalities depending on the squares of the eccentricities and the inclinations forbids to compute all of them; in our choice we are guided by the following considerations." These considerations relate to the occurrence of small coefficients of t or coefficients nearly equal to n, which in integrating produce large amplitudes. In the same way the perturbations

of Jupiter by the other planets are given, in a smaller number of terms, because they are smaller; the largest term produced by the earth is 0″.12, by Uranus 0″.05. The perturbations of Saturn caused by Jupiter are of course larger. Among Laplace's numerical results we find as the most important terms

$$+3''.2 \sin\theta - 31''.5 \sin 2\theta - 6''.6 \sin 3\theta - 2''.0 \sin 4\theta \ldots - 182''.1 \sin (1, 2, \pi')$$
$$+417''.1 \sin (1, 2, \pi) + 34''.3 \sin (2, 3, \pi') - 17''.7 \sin (2, 3, \pi),$$

and among the terms depending on the squares of the eccentricities there is one amounting to $-669''.7$ with $(2n' - 4n)\,t$ in the argument. Uranus produces here terms

$$+9''.2 \sin\theta - 14''.5 \sin 2\theta + 25''.2 \sin (3, 2, \pi').$$

The motion of the earth shows inequalities $5''.3 \sin\theta + 6''.0 \sin 2\theta$ and $3''.7 \sin (2, 1, \pi)$ due to Venus, $3''.5 \sin 2\theta$ due to Mars, $7''.1 \sin\theta$ due to Jupiter, in total 47 terms. So at the close of these computations Laplace says: "It suffices to remark here that before the discovery of these inequalities the errors of the best tables reached 35 or 40 minutes [we remember that his minutes were only 32″.4] and that they now do not surpass one minute. . . I have reason to believe that the preceding formulas computed with special care, will add a new precision to the tables of the motions in the planetary system."

Laplace's work was not only a comprehensive summary of what the 18th century had elaborated in exact computation of the planetary motions; it was at the same time the starting point for new progress in the next century. The exactness reached by his formulas, diminishing the errors to some few tens of seconds, was not adequate to the increasing exactness of the observations. The theorists of the 19th century built further upon the foundations laid by Laplace; more refined methods of analysis were devised, terms of higher order were considered and their number was increased. Bessel's functions, Cauchy's numbers, Hansen's product-series made easier the handling of elliptic developments. Leverrier who devoted his life to the exact computation of the planetary perturbations, included terms of the 7th order in eccentricity and inclination; thus the uncertainty of the tables and their deviation from observation went down to a few seconds of arc. Then a more general treatment consisting in a surveyable organization of manipulations up to the highest orders by means of his differential operators enabled Newcomb to establish in full completeness the theoretical system of planetary perturbations.

IV

One of the main puzzles of 18th century theory was the great inequality of Jupiter and Saturn. Halley had stated, and introduced (1695) in his tables, that Jupiter since many centuries was accelerating and Saturn was retarding. Should this go on in the same way, Jupiter approaching to the sun ever more, the stability of the solar system was

endangered. The Paris Academy in 1748 and again in 1752 offered a prize as reward for a good solution of the problem, but no satisfactory answer was received. Lambert perceived in 1773 that in the later years Jupiter was retarding, Saturn accelerating, so that it must be a periodic phenomenon. At last Laplace succeeded in finding (1784) the true explanation; and the treatment of this large mutual perturbation of the two planets occupies an important place in his Treatise.

It was the discovery of the importance of long-period inequalities in the planetary motions and of their origin from the occurrence of small divisors in the integrations. "It is especially in the motion of Jupiter and Saturn, the two largest bodies among the planets, that the mutual attraction of the planets is sensible. Their mean motions are nearly commensurable, since 5 times the motion of Saturn is nearly equal to 2 times that of Jupiter; the considerable inequalities arising out of this relation, the laws and the cause of which were unknown, for a long time seemed to make an exception to the law of universal attraction, and now are one of its most striking demonstrations. It is extremely interesting to see with what precision the two chief inequalities of these planets, the period of which comprises nine hundred years, satisfy the ancient and modern observations; the coming centuries will show this concordance ever more in their further development."

Thus, among the innumerable terms of different orders our attention is directed to those containing the sine or cosine of $5n't - 2nt + \ldots$. What is their period? The mean daily motion of Saturn is 120".455, of Jupiter 299".128, hence $5n' - 2n = 4".02 = n/74$ (Jup.); the entire circle is performed in 323,000 days = 74 Jupiter periods = 887 years. If, then, in the disturbing function a term occurs of this form:

$$d^2(\delta v)/dt^2 = Cn^2 \sin\{(5n' - 2n)\,t + \ldots\}$$

double integration affords a term in the perturbation in longitude

$$\delta v = -C\,[n^2/(5n' - 2n)^2]\,\sin\{(5n' - 2n)\,t + \ldots\}$$

Such a term in the disturbing force, through the small divisor, is increased more than 5000 times in the resulting longitude of the planet. A small acceleration working ever again in the same way for a long time produces a notable velocity, and this velocity during the same long time results in a large displacement. Thus terms in the disturbing function which are extremely small because they contain high powers of the eccentricities, can yet give rise to perceptible terms in the longitude. But here they are not extremely small. It is the 3rd power already of the eccentricities that appears in the coefficients of the terms in question; so the result is such a large perturbation as to alarm the astronomers during an entire century. Indeed we have such products as $e^3 \cos 3\,(nt + \epsilon - \pi) \times \sin 5\,(n't - nt + \epsilon' - \epsilon)$ producing $e^3 \sin (5n't - 2nt + 5\epsilon' - 2\epsilon - 3\pi)$, $e^2e' \cos 2\,(nt + \epsilon - \pi) \cos (n't + \epsilon' - \pi') \times \sin 4\,(n't - nt + \epsilon' - \epsilon)$ producing $e^2e' \sin (5n't - 2nt + 5\epsilon'$

$-2\epsilon\ -2\pi\ -\pi'$), $e'\gamma^2 \cos\ (n't + \epsilon'\ -\pi')\ \cos\ 2\ (nt\ +\epsilon\ -\Omega \times \sin$ $4\ (n't\ -nt\ +\epsilon'\ -\epsilon)$ producing $e'\gamma^2 \sin\ (5n't\ -2nt\ +5\epsilon'\ -2\epsilon\ -\pi'$ $-2\Omega)$, where γ stands for $\tan \frac{1}{2}\phi$. Thus Laplace in his development of the disturbing function finds six terms having the third order quantities

$$e^3,\ e^2e',\ ee'^2,\ e'^3,\ e\gamma^2 \text{ and } e'\gamma^2$$

in their coefficients, which have $(5n' - 2n)\ t$ in their argument, and thus after integration have $(5n' - 2n)^2$ as divisors. Taking them all together the result is

for Jupiter $\delta v = 1263''.8 \sin\ (5n't - 2nt + 5\epsilon' - 2\epsilon)\ +119''.5 \cos$ $(5n't - 2nt + 5\epsilon' - 2\epsilon)$,

for Saturn $\delta v = -2931.1 \sin\ (5n't - 2nt + 5\epsilon' - 2\epsilon)\ -223''.2 \cos$ $(5n't - 2nt + 5\epsilon' - 2\epsilon)$.

Thus Jupiter deviates up to 21′, Saturn up to 49′ from their regular places.

Laplace does not content himself with having explained this conspicuous irregularity. Terms of the 5th order in the eccentricity, which may be expected to be nearly 400 times smaller, will be very perceptible and have to be included into an exact derivation of the amplitudes. Terms of the second order with respect to the masses, which will be nearly one thousand times smaller also may be perceptible and have to be computed. Thus he says, in continuance of the words quoted above: "In order to make the comparison more easy for the astronomers I have extended the approximation up to terms dependent on the square of the disturbing force; so I may hope that the values I assigned to them will be only slightly different from what will be found from a long series of observations continued over an entire period." The resulting total values of the four above coefficients are 1237″.41, 112″.71, 2872″.84, and 261″.01.

The discovery of the origin of this large perturbation has directed the attention of Laplace and later theorists to look at inequalities of long period in the case of other planets too. Thus he found for Venus one of 1″.50 with argument $(5n' - 3n)\ t$ due to the earth, and 2″.01 with argument $(3n' - n)\ t$ due to Mars, and for the earth one of 1″.13 due to Venus. Uranus has an inequality of 132″.51 due to its mean motion being nearly 1/3 of Saturn's, with a period of 7 of its revolutions.

V

In Laplace's treatment of the perturbations in radius and longitude as enforced oscillations in a system oscillating with its proper frequency n, special terms arise in the case that the acting force has the same frequency. In that case (resonance) the force acts in the same way in every oscillation and tends to increase indefinitely the amplitude of the oscillation which, in the absence of resistances, must grow to infinity.

Mathematically this appears in such a way that by integrating

$$d^2y/dt^2 + n^2y = 2\ n\ p\ \cos\ (nt + \alpha)$$

we get

$$y = C_1 \cos\ nt + C_2 \sin\ nt + pt \sin\ (nt + \alpha),$$

so that the amplitude contains the factor t. Expressed in another way: the development of the disturbing function gives rise to terms that do not contain the sines or cosines, or have lost the time in their arguments; then by integration t appears as a factor in non-periodic terms. Such is the case with the term e^2 in the development of r/a. Such is the case also in the multiplication

$$A \cos\ (n't - nt + \epsilon - \epsilon') \times e \cos\ (nt + \epsilon - \pi) \times e' \cos\ (n't + \epsilon' - \pi')$$

which produces a term $1/4\ Aee' \cos\ (\pi' - \pi)$ where, if we restrict ourselves to the first power of the masses, $\pi' - \pi$ is a constant.

"The disturbing forces introduce . . . the time t outside the sine and cosine, or in the form of circular arcs which by their indefinite increase must make in the long run these expressions erroneous; hence it is essential to make these arcs disappear. . . As these variations take place with great slowness, they are denoted by the name 'secular inequalities.' Their theory is one of the most interesting parts of the world system; so we will expound it with all the ampleness that its importance demands." Indeed the exhaustive treatment of these secular perturbations by Laplace is a masterpiece of celestial mechanics and deserves the ample place devoted to it in his great work.

The equations determining the variations of the elliptical elements are derived by Laplace in a somewhat intricate way, making use of general considerations on differential equations. This part of the theory has been made far more direct and elegant in the next century by the introduction of canonical equations and canonical elements by Jacobi. In the practical elaboration of the equations, however, and their solution Laplace's treatment has remained classical up to modern times. Instead of the elements e and π he introduces the rectangular components, of e, *viz.*, $e \sin \pi = h$ and $e \cos \pi = l$ — representing rectangular coordinates of the focus, the sun, relative to the centre of the ellipse— and likewise the inclination is decomposed into $\tan \phi \sin \Omega = p$, $\tan \phi \cos \Omega = q$; they are called afterwards the eccentric and the oblique variables. Then the equations determining the secular perturbations of the elements are found to be

$$dn/dt = 0;\ d\epsilon/dt = 0 \text{ (by an appropriate definition of } \epsilon)$$
$$dh/dt = (0, 1)\ l - [0, 1]\ l';\ dl/dt = -(0, 1)\ h + [0, 1]\ h';$$
$$dp/dt = (0, 1)\ (q' - q);\ dq/dt = (0, 1)\ (p - p'),$$

where $(0, 1)$ and $[0, 1]$ represent expressions in the constants A and b and the masses of the two planets denoted by the index 0 and 1.

"The equation $dn/dt = 0$ just found is of great importance in the theory of the world system, since it shows that the mean motions of the

celestial bodies and the major axes of their orbits are unalterable; but the equation is approximate only. . . It is highly important to know whether higher powers of the eccentricity should disprove this result and produce terms with the time as factor. We will demonstrate that, with respect only to the first power of the disturbing masses, the expression for v, however far the approximations include higher powers of the eccentricities and inclinations, will not contain such terms." Then Laplace gives a demonstration along general lines that no terms with the time as a factor will occur, provided that the mean motions or the periods of revolution of the planets are not commensurable.

Turning now to the eccentricities we see that in the equations for each planet the time-differential of each component is a linear function of the other component, of itself and of the disturbing planet. Hence, since there were 7 planets at the time, it is a linear function of the other component of itself and of all the other six planets. This holds for every planet, so that we have a system of equations such as

$$dh_1/dt = a_{11}l_1 + a_{12}l_2 + a_{13}l_3 + \ldots + a_{17}l_7$$
$$-dl_1/dt = a_{11}h_1 + a_{12}h_2 + a_{13}h_3 + \ldots + a_{17}h_7$$
$$dh_2/dt = a_{21}l_1 + a_{22}l_2 + a_{23}l_3 + \ldots + a_{27}l_7$$

et cetera, where the a_{ij} are all known constant coefficients. Substituting in the second members the present values of h and l of the planets, considered as constants, we find the yearly variation of these elements, hence of e and π. But the equations can also be integrated analytically so as to give all these elements directly as functions of the time. Laplace shows that there are solutions of the form $h = N \sin(gt + \beta)$; $l = N \cos(gt + \beta)$, the argument $gt + \beta$ being identical for all the planets. They represent slow circular motions of the centre of the planet's ellipse about the sun in a period $2\pi/g$. By eliminating all the amplitudes N it appears that g is determined by an equation of the 7th degree, which has 7 different roots, all real and positive. Hence for any planet there are 7 circular motions of the centre of the orbit about the sun, combining each with its own period. The periods and phases are the same for all the seven planets, but the radii or amplitudes are different. Laplace computed and gives all the coefficients a_{ij} of the equations; but he did not compute, at least does not give, the periods themselves and the radii of the circular motions, probably because, amounting to ten thousands of years or more, they lie far outside any practical application and any test. In their stead he derives and gives the yearly variations of the elements for each of the planets for the year 1750.

Analogous results are found for the secular changes in the components of the inclination p and q. Their representation by a circular function means that the pole of the orbit describes at the celestial sphere a small circle about the pole of the plane of reference. Here also we have 7 circular motions with very long but different periods, with iden-

tical periods but different radii for the different planets. Here also Laplace does not give the periods but only the yearly variations of the elements, inclination and node, for 1750.

A special discussion is devoted to the stability of the planetary system. It depends on the character of the roots of the 7th degree equation for g. Should some of them be equal or complex, then the sines and cosines would turn into arcs or into exponentials, so that the eccentricities could increase indefinitely and the stability of the system would be destroyed. Laplace now shows that the sum total of the expressions $e^2 m\sqrt{a}$ for all the planets must always remain equal to the same constant value, which for our planetary system is a small quantity. Then each of the terms must remain less than this constant, provided that they all are positive, *i.e.*, that all planets revolve about the sun in the same direction. And he shows that in this case all the roots g are real and different. "Hence the system of orbits is perfectly stable in regard to their eccentricities; the orbits only oscillate about an average state of ellipticity, from which they deviate little, keeping their major axes constant."

The same holds for the inclinations. From the general dynamical principles he had derived already that there exists an "invariable plane," the plane of maximum moment of momentum for the entire system, the natural plane of reference for the separate orbits. Moreover he finds that the sum total of $m\sqrt{a}\tan^2\phi$ for all the planets is equal to a constant. This constant being rather small, it follows that all the inclinations will remain small, except for a planet with very small mass. Leverrier afterwards computed that for Mercury the extremes for eccentricity and inclination are 0.226 and 9°.17.

The importance of these researches consisted in that they raised in science and in the minds of the scientists the problem of the future, the durability of the world. When in the 17th and 18th century continuous changes were discovered in the orbits of the planets and the moon, it was feared that they could in the long run destroy the structure of the system. When theory attributed them to the mutual attraction of the celestial bodies the question was asked whether the perturbations could increase to such amounts as to upset the prevailing order. Laplace here gave the first reassuring answer in demonstrating the stability of the solar system in regard to the mechanical effects of the mutual attraction. The impression it made upon contemporary minds can be found reflected in nearly all popular books on astronomy from the first half of the 19th century, often with reference to the wisdom of the Creator who, by having made all the planets revolve in the same direction and their orbits nearly circular and little inclined, had provided for the eternity of the world structure on which our life depends.

Laplace himself, however, had already pointed out the restriction in this demonstration; the simple expressions derived for the secular in-

equalities were only approximate, since the higher powers of eccentricity and inclination had been neglected; and the invariability of the major axis was only proved for the first power of the masses. Later theorists then, of course, have tried to improve the work. Poisson demonstrated that the stability of the major axis also holds for attractions depending on the second power of the masses. An absolute demonstration free from all approximations, however, that the system will keep its structure under the mutual attractions for indefinite times, will hardly be possible.

Nor does it appear necessary today. The attitude of science towards this problem has changed. At the time of Laplace past and future of the world was a problem of mechanics; mechanics was the only discipline that had acquired the high character of scientific exactness. The world was not considered invariable; the solar system had developed out of different primeval conditions into its present state, as exposed in the Nebular Hypothesis by Laplace himself, and earlier already devised by the German philosopher Kant. But this present state, once acquired, was to be its lasting and final state, to persist indefinitely. It was the same trend of thought then prevailing in social and political theory that appeared here in cosmical theory. In the 19th century, however, new points of view came forward. Physics developed into an exact science discovering and formulating its fundamental laws of nature; and it showed the entire world to be in a state of continual evolution, as expressed in the second law of thermodynamics, the law of entropy. In the biological, the social, the political world both experience and theory pointed to incessant change and evolution. There is no final state to last for ever. The future of our life on earth, now, is seen to depend much more on radiation than on gravitation. As to their fundamental importance for human existence the astrophysical problems of energy transition have superseded the mechanical problems of planetary motion. Planetary theories, that during the past centuries of human history gave the great impulse to scientific progress, now have finished their task.

A Simplified Method of Finding the Greenwich Hour Angle of a Planet

By PAUL E. WYLIE

The *American Nautical Almanac* tabulates the Greenwich Hour Angle (GHA) of the planets Venus, Mars, Jupiter, and Saturn, for the beginning (zero hour) of each calendar day. Opposite each entry is given the rate, to four decimal places, at which the hour angle of the planet increases, in minutes of arc per minute of time, during the day following. Accompanying the ephemerides of the planets, exten-

sive interpolation tables are printed, giving, in columns for specified rates of increase of hour angle per minute, the corresponding total increase of the Greenwich Hour Angle, for increments of time ranging up to 24 hours. These tables are in three parts: a series for hours, another for minutes, and the last for seconds. In the first two of these tables, one must interpolate between tabular values. The third, for seconds, is based upon a constant increase of hour angle of 15″ per second of time. The interpolated quantities taken from the three tables are added to the GHA for zero hours. The result is, closely enough, the GHA at the time in which we are interested, and which we shall call the time of observation.

Since the method described is slow and complicated, it becomes of interest to seek a simpler and more direct method of finding the GHA of a planet at any time by the use of the existing *Almanac*—a method which will not involve the use of the interpolation tables. For this purpose, the following method is suggested:

(a) Interpolate between the values of GHA given for zero hour of the day involved and zero hour of the next day following, in proportion to the Greenwich Civil Time (GCT) of observation.

(b) To the arc found as described in (a), add the GCT of observation, expressed in degrees. The sum will be the GHA at the time of observation.

The following example illustrates the method:

Find the GHA of Mars, 1945 Oct. 7; GCT 18h 12m 0s = 273° 0.0′

From the *Almanac:* GHA Mars, Oct. 7 GCT 0h	267° 53.8′
From the *Almanac:* GHA Mars, Oct. 8 GCT 0h	268° 21.0′
Difference	+27.2′
Proportioning the difference: $\frac{18.2}{24} \times 27.2' = 20.6'$	
Adding the quantities:	
GHA 0h Oct. 7	267° 53.8′
Correction for 18.2 h	20.6′
GCT	273° 00.0′
GHA	181° 14.4′

The theoretical justification of the method is as follows:

Let a = GHA at 0h (from the *Almanac*)
b = GHA at 25h (from the *Almanac*)
d = b − a
Δa = increase of "a," per degree increase in time after 0h
t = GCT in degrees
t_h = GCT in hours

Then, GHA at any time = $a + t\Delta a$ (1)

GHA at 25h = $a + 360\Delta a = a + 360 + d$ (2)

From (2) $\Delta a = \frac{360 + d}{360} = 1 + \frac{d}{360}$ (3)

Substituting this value of Δa in (1), we have

$$\text{GHA at any time} = a + (1 + d/360)\, t$$

$$= a + \frac{t}{360}\, d + t$$

$$= a + \frac{t_h}{24}\, d + t$$

This last expression is a mathematical statement of the rules heretofore given.

In classroom test, the writer has found that students prefer the method outlined in this paper; that student determinations of GHA made by its use are more accurate than those found by the *Nautical Almanac* interpolation tables; and that it is faster. Practical tests at sea, by ship's officers, are contemplated.

UNIVERSITY OF CALIFORNIA, LOS ANGELES, CALIFORNIA, APRIL 30, 1948.

A Tribute to Miss Anne S. Young

At the spring meeting of the American Association of Variable Star Observers on May 22, 1948, at John Payson Williston Observatory, at Mount Holyoke College, one of the major events was the unveiling of a photograph of Professor-Emeritus Anne Sewell Young, who for 37 years was Director of that Observatory. The photograph and a piece of teaching equipment were presented to the Observatory by the astronomical alumnae of Mount Holyoke though other friends of Miss Young, who heard of the project, asked to be included.

Since her retirement in 1936 Miss Anne Young has been living with her sister, Miss Elizabeth, in Claremont, California. It was arranged that at the moment the picture was being unveiled in South Hadley, a corsage of orchids from her former students would be delivered to Miss Young in California, as well as a telegram of greetings from the Council of the A.A.V.S.O.

Miss Anne S. Young comes by her astronomical intesest naturally, as her uncle was the famous astronomer Charles A. Young of Dartmouth and Princeton, noted for his work on solar eclipses, as well as for his text books which, original and revised, have been used extensively by astronomers for over half a century. Over a period of many years in Mount Holyoke's middle history he served as lecturer, making biennial visits to the campus.

Miss Young received the bachelor's degree from Carleton in 1892, and the M.S. from the same college in 1897. She taught astronomy and mathematics in Whitman College, Walla Walla, Washington, from 1892 to 1895, and was principal of the high school at St. Charles, Illinois, for one year. She came to Mount Holyoke in 1899, succeeding Miss Elizabeth Bardwell, who had taught astronomy from 1866. Miss

Young did graduate work at the University of Chicago and received her Ph.D. in 1906 from Columbia, her thesis, an investigation of the double cluster in Perseus, being the 17th of the contributions from the Observatory of Columbia University to be based on measurements of the Rutherford Stellar Photographs. During her years at Mount Holyoke she continued her keen interest in measurement of celestial photographs and orbit work, as well as extensive work on variable star observations, and the observation and reduction of occultations.

For the actual unveiling ceremony at the Observatory, the lecture room was filled to capacity with members of the A.A.V.S.O., and college friends of Miss Young. The photograph of Miss Young is one taken in her earlier years at Mount Holyoke, skilfully enlarged under the direction of Miss Mary Calvert formerly of the Yerkes Observatory, now of Nashville, Tennessee.

The actual presentation of the photograph was made by Dr. Helen Sawyer Hogg of the David Dunlap Observatory, Toronto, who majored in astronomy under Miss Young, and later taught in the department. Miss Edith Flather, a present-day astronomy major, removed the star-studded veil from the picture.

Mrs. Hogg told briefly of Miss Young's life and of her remarkable powers as a teacher. Many spontaneous tributes from former students had been received in connection with the project, two of which were quoted as summarizing the feeling of Miss Young's students toward her. A former assistant in the department wrote, "The student who said to me 'The book isn't anything compared to Miss Young' expressed the feeling of all of us concerning her work." Another student wrote, "That there should be a picture of Miss Young in the Mount Holyoke Observatory seems to me almost as essential as the telescope."

Mrs. Hogg stressed the careful precision of Miss Young's teaching, and especially the personal interest she had in her students, with whom she has kept in close contact through the years by a voluminous personal correspondence. Mrs. Hogg told particularly of the great event of the total eclipse of the sun of January 24, 1925. For this occasion Miss Young's astronomical enthusiasm and powers of organization were so great that she was able to achieve a major engineering feat of moving 800 members of the College, who arose at 5:30 on a below-zero January morning, by special train of ten cars to Windsor, Connecticut, where, by standing on a snow-covered golf course at 4° below zero, they were treated to the magnificent spectacle of a total eclipse of the sun. (Later, at the close of the ceremony, Mr. Percy Witherell of Boston, commented, "Never underestimate the power of a woman. Harvard refused to suspend examinations in order to let its students go to see the total eclipse, and finally compromised by letting them out into the yard when the eclipse was on to see the partial eclipse!")

Dr. Alice Farnsworth, former student under Miss Young, her junior colleague for many years, and the present director of John Payson

Williston Observatory, accepted the gift of the photograph and equipment, and commented on some of the elements that made Miss Young a great teacher: contagious enthusiasm for her subject, scrupulously high standards, and unstinting effort directed to giving her students the best possible training at the same time that she gave them her warm personal interest and understanding.

Mr. Leon Campbell, Recorder of the A.A.V.S.O., whose years of service in that organization are comparable in number with Miss Young's, told of her active and long-continued interest in variable-star work. He mentioned that just two observers, Anne S. Young and William Tyler Olcott, contributed to the first monthly report of variable-star observations submitted in 1911. Mr. Campbell concluded by reading the telegram of greetings and congratulations sent to Miss Young from the Council of the A.A.V.S.O.

The ceremony was greatly enjoyed by all who attended. Many of Miss Young's "girls" who would have enjoyed it most were unable to be present except in spirit. From all parts of the country, north and south, east and west, came warm tributes showing that the influence of a great teacher is truly nation-wide.

The Planets in July and August, 1948

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac*.

Sun. The sun will have begun its southward retreat, passing from 23 degrees north of the equator at the beginning of this period to only 9 degrees north at the end. It is farthest from the earth on July 4.

Moon. The phases of the moon will occur as follows:

New Moon	July	6	3 P.M.
First Quarter		13	6 A.M.
Full Moon		20	9 P.M.
Last Quarter		29	1 A.M.
New Moon	August	4	10 P.M.
First Quarter		11	2 P.M.
Full Moon		19	12 NOON
Last Quarter		27	1 P.M.

The moon will be nearest to the earth on July 23 and August 20.

An occultation of the star τ Sagittarii, beginning at about 11 P.M. on August 15, will be conveniently visible from the southeastern section of the country, including Washington, D. C.

Evening and Morning Stars. Mars and Jupiter will be evening stars during both months; Saturn will be visible only in July. Venus will become conspicuous in the morning twilight early in July.

Mercury. Mercury will reach a maximum western elongation of 21 degrees

on July 21, and thus may be seen low in the eastern dawn within a week or so of that date. It will be practically invisible during August, since it passes superior conjunction on the 11th.

Venus. After having reappeared in the morning sky, Venus will reach greatest brilliance on July 31. By the end of August it will have receded to 45 degrees west of the sun, so that it will rise as early as 2 A.M.

Mars. Because of its rapid eastward motion, Mars will remain more than 3 hours east of the sun during all this period. However, its increasing distance from us and more southerly position will gradually render it much less conspicuous.

Jupiter. Jupiter will be the most brilliant object in the southeastern evening sky during all this period.

Saturn. By late July Saturn will have disappeared in the evening twilight since it comes to conjunction with the sun on August 19.

Uranus. Uranus will be moving slowly eastward along the ecliptic at a position 4 degrees east-northeast of ζ Tauri.

Neptune. Neptune will be moving very slowly southeastward at a position 2 degrees south of γ Virginis. On August 8 at 7 P.M. it will be less than a degree south of the crescent moon.

Department of Mathematics, Temple University, Philadelphia, Pa.,
May 1, 1948.

Occultation Predictions for July and August, 1948

(Taken from the *Amerian Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

			IMMERSION				EMERSION			
Date 1948	Star	Mag.	Greenwich C.T.	*a*	*b*	Angle E from N	Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°	h m	m	m	°
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′										
July 12	10 Virg	6.1	0 55.5	—2.2	—0.2	59	1 22.8	+0.4	—3.3	9
17	22 Scor	4.9	2 46.3	—1.9	—0.8	108	4 9.3	—1.6	—1.2	280
19	48 G.Sgtr	6.3	0 3.1	—0.2	—0.2	145	0 57.8	—2.2	+1.9	236
31	*A* Taur	4.5	6 27.5	+0.2	+1.6	63	7 24.5	—0.2	+1.7	249
31	39 Taur	6.0	6 41.4	—0.2	+1.3	91	7 33.7	+0.1	+2.1	221
Aug. 13	41 G.Scor	6.4	1 20.3	—1.8	—1.1	109	2 40.4	—1.3	—1.4	279
15	38 B.Sgtr	4.7	3 16.1	—2.4	—2.2	139	4 4.6	—0.4	+0.4	212
17	*A* Sgtr	5.0	4 16.9	—0.3	+1.7	12	5 2.3	—3.0	—2.5	308
26	124 B.Arie	6.4	4 58.0	—0.6	+1.6	83	5 58.5	—0.3	+2.4	214
27	22 H'Taur	6.0	5 15.2	—0.3	+1.6	76	6 16.6	—0.3	+2.1	230
29	BD+26°884	6.5	5 34.5	+0.6	+1.9	41	6 19.2	—0.4	+0.8	291

OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′

July	2	o Arie	5.8	9	11.4	+0.1	+2.2	30	10	5.9	−0.9	+1.4	268
	17	22 Scor	4.9	2	13.2	−1.6	−0.5	127	3	36.7	−2.2	−0.4	274
	23	161 B.Capr	6.4	10	12.1	−2.4	−1.7	102	11	4.6	+0.3	+1.7	190
	31	39 Taur	6.0	6	40.4	+0.4	+1.2	77	7	32.1	+0.3	+1.6	239
Aug.	13	41 G.Scor	6.4	0	47.7	−1.8	−0.7	125	2	11.9	−2.0	−0.8	276
	15	38 B.Sgtr	4.7	2	36.9	−2.1	−1.0	136	3	42.1	−1.8	+0.5	228
	21	ψ^2 Aqar	4.6	9	34.2	−1.0	+0.5	46	10	49.0	−0.8	−0.2	240
	26	124 B.Arie	6.4	4	49.7	+0.1	+1.6	68	5	48.6	−0.2	+1.9	235
	27	22 H¹Taur	6.0	5	11.9	+0.3	+1.6	60	6	7.9	−0.1	+1.6	250

OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +30° 0′

July	2	o Arie	5.8	8	52.1	+0.2	+1.8	41	9	47.5	−0.5	+1.3	259
	17	22 Scor	4.9	2	14.8	−0.7	−2.0	161	3	17.2	−3.4	+0.9	247
	23	161 B.Capr	6.4	10	12.7	..	..	124	10	39.3	..	..	161
Aug.	13	41 G.Scor	6.4	0	48.3	−1.2	−1.9	155	1	58.1	−3.1	+0.3	253
	15	38 B.Sgrt	4.7	2	46.2	..	..	174	3	6.3	..	..	197
	16	τ Sgtr	3.4	4	57.0	..	..	9	5	30.3	..	..	326
	17	ω Sgtr	4.8	0	52.9	−2.1	+3.0	39	1	46.1	−1.0	−0.9	317
	17	A Sgtr	5.0	3	9.0	−2.6	+3.9	19	3	58.3	−3.3	−2.3	318
	21	ψ^2 Aqar	4.6	9	18.3	−1.8	+0.7	59	10	39.1	−0.8	+1.0	219
	24	263 B.Pisc	6.4	11	12.5	..	..	354	12	0.2	−3.2	−2.6	288
	27	32 Taur	5.8	12	14.9	−2.3	+1.1	66	13	46.6	−2.2	+0.5	247
	31	ω Canc	5.9	11	0.6	−0.8	+0.2	114	12	1.0	−0.8	+1.6	251

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′

July	23	161 B.Capr	6.4	9	7.9	−2.0	+1.3	56	10	38.6	−1.8	+0.7	236
	25	351 B.Aqar	6.5	12	52.5	..	..	117	13	24.0	..	..	161
	28	o Pisc	4.5	12	9.7	−2.1	+1.3	71	13	29.6	−1.2	+2.3	209
	31	192 B.Taur	6.2	9	52.6	−0.8	0.0	127	10	20.6	+1.0	+3.1	186
Aug.	15	48 G.Sgtr	6.3	7	28.5	−1.8	−1.4	103	8	39.7	−0.5	−0.4	240
	17	A Sgtr	5.0	2	31.6	−2.5	+3.9	24	3	9.2	−0.4	−1.4	329
	21	ψ^2 Aqar	4.6	9	8.6	+0.7	+3.7	350	9	54.3	−4.1	−1.6	287
	27	32 Taur	5.8	12	1.1	+0.3	+4.5	3	12	46.9	−3.6	−1.8	298
	31	ω Canc	5.9	11	2.6	+0.4	+1.6	66	11	52.6	−0.5	+0.3	298
	31	4 Canc	6.2	11	25.3	−0.6	−0.1	132	12	8.9	+0.2	+2.3	232

Asteroid Notes

By HUGH S. RICE

A few weeks ago we received a copy of *Minor Planets for 1947*, published by the Cincinnati Observatory, under the sponsorship of the International Astronomical Union. This small book is a continuation of the *Kleine Planeten* series formerly published annually by the German asteroid headquarters. This headquarters was first known as the Astronomische Rechen-Institut, then as the Coppernicus-Institut; and now the name has been changed back to the Rechen-Institut.

The present (1947) volume is a catalog of 1563 asteroids, giving elements, opposition dates for the planets during the year, ephemerides of each planet for about 6 weeks around opposition, and other data. The whole work represents a large undertaking and is a coöperative effort by 15 institutions. The four American participants are located at Berkeley, Cincinnati, New Haven, and New York. The style and size of the booklet are similar to those of the old *K. P.*, and curiously enough the paper-stock and printed border on the cover appear to be identical with the *K. P.* Among other things, the book is of advantage to astronomers who made photos of minor planets during 1947.

The Institute of Theoretical Astronomy, Leningrad, was supposed to have

been computing all the 1948 ephemerides, but up to a late date none of this has been received, so far as known, in this country. However, the Rechen-Institut has been occupied with the work and has issued ephemerides of selected planets for the first half of the year, so far, and is now engaged on the work of the last half. The computation is the result of a joint effort of the R. I. in Heidelberg and of the Baden Observatory of Königstuhl.

We offer positions of four asteroids for summer observation, these being the brightest ones available among many other faint ones. 423 DIOTIMA is found near θ Ophiuchi; it comes to opposition on June 13, and its photographic magnitude then is predicted as 11.0. The visual magnitudes are commonly one magnitude (or less) brighter than the photographic. 9 METIS is in western Sagittarius; it comes to opposition on June 20, with photo-magnitude 9.5. 67 ASIA is at the Aquila-Aquarius border, and comes to opposition on July 27, with photo-magnitude 9.9. 172 BAUCIS is in eastern Capricornus and has its opposition on August 15, with photo-magnitude 9.6.

These ephemerides are partly from the Cincinnati Observatory and partly from the Rechen-Institut, except that the positions for dates in parentheses are extrapolated by us, in order to make the ephemeris cover better the observing period of this issue, *viz.*, from June 15 to August 15.

ASTEROID EPHEMERIDES

For 0^h U.T. Equinox 1950.0

423 DIOTIMA			9 METIS		
	α	δ		α	δ
1948	h m	° ′	1948	h m	° ′
June 10	17 31.9	−26 56	June 10	18 9.0	−26 7
18	17 24.5	−27 18	18	18 0.5	−26 25
26	17 17.2	−27 37	26	17 51.8	−26 39
July 4	17 10.5	−27 52	July 4	17 43.8	−26 49
(12)	17 4.9	−28 3	12	17 35.9	−26 51
			(20)	17 29.9	−26 45

67 ASIA			172 BAUCIS		
	α	δ		α	δ
1948	h m	° ′	1948	h m	° ′
June (26)	20 44.9	− 6 35	July (20)	22 5.0	−18 20
July 4	20 42.9	− 6 19	28	21 58.8	−18 15
12	20 38.6	− 6 15	Aug. 5	21 51.1	−18 7
20	20 33.1	− 6 25	13	21 42.6	−17 56
28	20 26.6	− 6 51	21	21 33.5	−17 43
Aug. 5	20 20.2	− 7 27	29	21 25.2	−17 24
13	20 14.5	− 8 12			

Hayden Planetarium, American Museum of Natural History,
New York, N. Y., May 19, 1948.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

The writer has often remarked in Meteor Notes that quantities of data were piled up in our files which he personally has not been able to reduce. For several years, has he had no day assistants to whom such work could safely be committed. Hence often there is a long and undesirable delay before results appear,

though such delays have been inevitable. Having recently had occasion to go through records of 1936 and 1937, I was struck by the fact that several excellent observers had sent in large numbers of plotted meteors but their maps had been only partly studied. Having a little time that could be devoted to this matter, many of these maps have just been worked up. They are part of the meteor work done for those years by Vincent Anyzeski, Gordon Green, and B. S. Whitney. In the table which accompanies these remarks will be found the A.M.S. radiants No. 2480 to 2500 (except No. 2488) and 2999 to 3022 inclusive. Their publication will now pretty well fill up all the numbers to 3022 except those reserved for unpublished fireballs, namely No. 2310 to 2400. From now on we hope to maintain a more regular system by using numbers as they come, in order.

In Flower Observatory Reprints Nos. 37, 41, and 46, which contain respectively the Meteor Notes for 1936, 1937, and 1938, will be found part of the tabular data for the three observers mentioned above, as well as some of their radiants for 1936 and 1937. They sent in so much, however, that even yet more remains to be deduced, and it should be added that each had observed enough to become skilful, hence their plots are worthy of full reduction. In passing, it is hard to make many observers understand that nobody plots well at first, and skill only comes with practice, hence that radiants in which we would have confidence cannot be deduced from the plots of many persons who work only occasionally.

The table of radiants has columns which give for each radiant respectively: the A.M.S. serial number; the date in (old astronomical beginning at noon) G.M.T.; the right ascension and declination of the radiant (with no corrections of any kind); the number of meteors whose paths were actually used in deriving the radiant; the presumed accuracy of the radiant on the scale good, fairly good, fair, and poor; the observer's name, and notes. These latter give the name of the stream furnishing the radiant, in some cases; in others former A.M.S. radiants which seem to confirm its reality. The search for confirmations was only partially complete. If only 4 meteors or less were available, its retention in the table generally is based upon some additional reason.

With regard to the Delta Aquarid and Perseid streams, the Moon is at last quarter on July 29, hence will be quite near the radiant of the former at its maximum, which should occur on July 28. This will be somewhat unfortunate, but as these meteors continue for at least a week, during the first days of August moonlight will steadily decrease to zero on August 5 so any date from August 1 on should give good results. This is doubly true because long before this the Perseids should be coming in some numbers. The Moon will be at first quarter on August 11, the very night of the probable Perseid maximum. But as so many more meteors are seen after than before midnight, it should interfere comparatively little. It is hoped that many groups will therefore make extensive preparations to observe not only in the routine manner but also simultaneously for heights and in other more advanced programs. They should of course plan so that if one night is cloudy at least an alternate one is available. Supplies of maps, blanks, etc., should be asked for by mid-July as the writer expects to be away part of the summer, and such requisitions are likely to be delayed badly unless he is here to pass on what requests are reasonable and what are not. Again observers are asked always to take with them an opera glass or field glass so that, if a long-enduring train is sighted, they may follow it by such optical means, thus often doubling the time it remains visible and giving better chances

for getting an accurate idea of its direction of drift and changes of shape.

Flower Observatory Reprints Nos. 68 and 69 have been sent to all active observers who have paid their 1948 dues; will those still delinquent please pay without further delay.

A recent rather unpleasant incident concerning a supposed meteorite, sent to me for examination and inadvertently laid aside and forgotten, prompts me to make the following statement. The American Meteor Society concerns itself with meteoric bodies while they are out in space or in the Earth's atmosphere. Once they reach the ground their analysis and study must be undertaken by persons trained in mineralogy. The writer does not belong to this group and we have no facilities at Flower Observatory for analyzing specimens sent to us. Hence I request our members and others not to send (supposed?) meteorites for me to pass upon, since all I can do is to hand them on to others, unless the specimen is obviously terrestrial—as many are! Long since I made an arrangement with the Department of Mineralogy of the U. S. National Museum, Washington, D. C., by which such specimens would be examined and, if necessary, analyzed there without charge to the sender, and the latter notified of the verdict. So instead of mailing such specimens to me please send them to Dr. E. P. Henderson using the above address, at the same time writing him the fullest description of why you believe the thing to be a meteorite. This should include all phenomena dealing with its fall, if seen, the exact time and place it was found, the kind of soil it lay in, depth of hole, etc. Here at Flower Observatory I could fill a large show case with specimens sent me throughout the years and not worth returning as they were ordinary rocks. Some people are prone to think any stone that looks unusual to them must be a meteorite. Alas, few are! In fact in some states, I believe, to date no authentic meteorite has ever been found within their boundaries. These remarks are not meant to discourage anyone who has real reason for suspecting that he has found a meteorite from sending it to the proper place for examination, but do have some reason further than the wish that it may be one. Our sister society, The Meteoritical Society, is in any case the more logical group to discuss meteorites, not the A.M.S. It is probable that the two societies will eventually unite, as many of us belong to both, but there are practical difficulties, for the time being, and in a country as large as the United States we can both work side by side meantime with great effectiveness.

A.M.S. No.	Date 1936	R.A.	Decl.	Meteors	Accuracy	Observer and Notes
2480	Aug. 6.7	43°.3	+54°.0	3	Good	B. S. Whitney, Perseids
2481	Aug. 9.7	42.3	+56.4	8+	Good	G. Green, Perseids
2482	Aug. 11.7	44.2	+57.5	14	V.Good	G. Green, Perseids
2483	Aug. 17.7	49	+19.5	4	F. Good	G. Green, Perseids
2484	Aug. 17.7	53.5	+58.2	4	V. Good	G. Green, Perseids
2485	Sept. 19.8	62.5	+23.3	6-9	V. Good	G. Green, 2193
2486	July 6.7	264	+ 2	4	Good	B. S. Whitney
2487	July 27.7	279	+37.5	4	Good	B. S. Whitney
2489	July 27.7	286	+21	4	Good	B. S. Whitney, 2 also on July 26
2490	Aug. 3 to 6	309.5	+ 4.5	6-8	Good	B. S. Whitney
2491	Aug. 6.7	310	+ 6	6	Good	B. S. Whitney
2492	Aug. 3.7	325	—15	6-9	Fair	B. S. Whitney
2493	Aug. 6.7	325	+ 7	4	Good	B. S. Whitney
2494	Aug. 5 to 7	339	—15	4	F. Good	B. S. Whitney, δ Aquarids
2495	July 26.7	343	—10	4+	Fair	B. S. Whitney, δ Aquarids
2496	Aug. 3.7	347	0	8	F. Good	B. S. Whitney, 1173?

No. A.M.S.	1936 Date	R.A.	Decl.	Meteors	Accuracy	Observer and Notes
2497	July 17.9	347.5	+25	4	F. Good	B. S. Whitney
2498	Aug. 17.7	351	+62	3-5	F. Good	G. Green, 1193, 4110
2499	Aug. 3.7	353	—29	6-8	Good	B. S. Whitney, 2766, 2756
2500	July 17.9	359	+12	4-6	F. Good	B. S. Whitney
2999	Oct. 30.7	17	+37	5	V. Good	V. Anyzeski
3000	Sept. 9.6	23	+27.3	6	Good	V. Anyzeski
3001	Nov. 29.6	32	+30	6	Good	V. Anyzeski
3002	Nov. 29.6	39	+50	6	Good	V. Anyzeski
3003	Nov. 30.8	79	+20	4	Good	V. Anyzeski, 741, 1604?
3004	Nov. 30.8	85	+42	3+	Good	V. Anyzeski, 758
3005	Dec. 1.7	93	+14	6	Fair	V. Anyzeski
3006	Dec. 3.7	99	+15	8±	F. Good	V. Anyzeski
3007	Dec. 7.7	103	+33	2-3	Fair	V. Anyzeski } 2876, 301, 2668
3008	Dec. 10.8	103	+35	5+	Good	V. Anyzeski } probably Geminid
3009	Dec. 9	105	31	12	Fair	V. Anyzeski } branch
3010	Dec. 12.8	105	+33.5	4-5	Good	V. Anyzeski }
3011	Dec. 7.7	112	+29	6	Good	V. Anyzeski, Geminids
3012	Dec. 10.8	112	+29.5	14+	Good	V. Anyzeski, Geminids
3013	Dec. 12.8	110.5	+31.5	30+	Good	V. Anyzeski, Geminids
3014	Dec. 13.7	113.5	+33.5	10	Good	V. Anyzeski, Geminids
3015	Dec. 14.6	112.5	+33	3	Good	V. Anyzeski, Geminids
3016	Dec. 7.7	145	+55	5-6	Good	V. Anyzeski
3017	Sept. 8.6	266	+53	8±	Fair	V. Anyzeski
3018	Sept. 9.6	314.5	+50.5	5	Good	V. Anyzeski
3019	Sept. 8.6	331	+31.5	6	F. Good	V. Anyzeski
3020	Sept. 9.6	332	+24.5	3	Good	V. Anyzeski }
3021	Sept. 8.6	334	+24.5	5	F. Good	V. Anyzeski } 1182?
3022	Sept. 8.6	341	+52	5	Good	V. Anyzeski

Flower Observatory, Upper Darby, Pa., 1948 May 5.

Contributions of The Meteoritical Society

(Known Formerly as The Society for Research on Meteorites)

Edited by FREDERICK C. LEONARD

Department of Astronomy, University of California, Los Angeles 24

The Exhibit of the Institute of Meteoritics at the 46th Annual Meeting of the American Anthropological Association, December 26 to 31, 1947

LINCOLN LA PAZ

Institute of Meteoritics, University of New Mexico, Albuquerque

Meteoritics is, *par excellence,* the science deriving from and contributing to almost all the other sciences. A new illustration of this reciprocal relationship was given at the National Meeting of the American Anthropological Association at the University of New Mexico, from December 26 to 31, 1947. By invitation of Dr. W. W. Hill, the Head of the Department of Anthropology of the University of New Mexico, a meteoritical exhibit, shown in part in the accompanying photograph (Fig. 1), was prepared by the Institute of Meteoritics for display in the Anthropological Museum, which served as headquarters for the meeting.

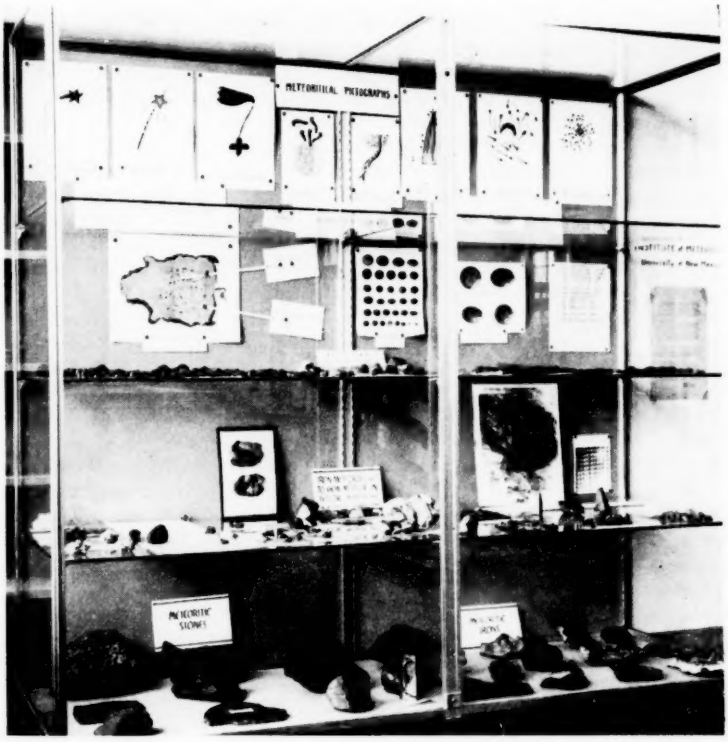

FIG. 1
THE EXHIBIT OF THE INSTITUTE OF METEORITICS AT THE 46TH ANNUAL MEETING OF THE A.A.A., DECEMBER, 1947

In addition to specimens of typical meteorites and pseudo-meteorites, the exhibit included samples of tektites and pseudo-tektites, since these substances rival the obsidians as material for arrowheads and other artifacts, and, consequently (during all excavating work), should be watched for, not only in their natural form, but also as points, scrapers, and knives. An effort was made to make clear to the visiting scientists who studied the exhibit of the Institute of Meteoritics, that, altho the tektites present interesting analogies to other natural glasses, they are distinguished from the latter by greater density and index of refraction, by higher melting-point and freedom from included gases, and by chemical peculiarities; and the simple blowpipe test for distinguishing genuine tektites from common obsidian was called to the attention of ethnologists, archeologists, and anthropologists. (Recent attempts to identify as tektites symmetric pebbles of obsidian from the neighborhood of Del Rio, Texas, suggest that not even all meteoriticists are familiar with this test.)

To A.A.A. members, the high point of interest of the exhibit was, understandably, the display of heretofore neglected meteoritical pictographs (see the paper following this note). This display, accompanied by a considerable amount of documentation, made out a strong case for the desirability of the coöperation of members of the A.A.A. in discovering and putting on record additional drawings, paintings, and carvings depicting meteoritical phenomena.

It is hoped that the exhibit of the Institute of Meteoritics will aid members of the A.A.A., specializing in the study of the pictographs left by early man, constantly to keep in mind the fact that the rare but impressive spectacles of meteorite falls and star-showers are portrayed in one guise or another in the pictographic record of the past. Once this fact becomes a part of the thinking of these specialists, this record will certainly be made to yield much valuable information concerning meteoritical activity in earlier times.

Meteoritical Pictographs

Lincoln La Paz
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ABSTRACT

This paper calls attention to certain undoubtedly genuine meteoritical pictographs and to other examples of picture-writing that probably have meteoritical significance. It is urged that anthropologists, archeologists, and ethnologists coöperate with meteoriticists in the collection, collation, and dating of pictographs portraying meteoritical phenomena.

Introduction.—The pictographs left by paleolithic man do not suggest that he paid any attention to the Sun, the Moon, or the stars. One cannot, however, infer from the failure, up to the present, to discover any attempts at the portrayal of these familiar objects, that early man ignored also the unusual and spectacular phenomena of meteor showers and meteorite falls. The Moon, the planets, the fixed stars, and, except for its greater light and heat, the Sun, did not in any way force themselves upon the developing consciousness of Man of the Old Stone Age; instead, without sudden motion and without sound, they remained aloof from him in the remoteness of the sky. It was quite otherwise with the sudden, startling appearance of myriads of shooting-stars, darting swiftly out of the heavens to fall like a fiery snowstorm into the very faces of the beholders, or with the Earth-shaking tumult accompanying meteorite falls. To these unfamiliar and violently obtrusive visitations, he no doubt reacted with frightened curiosity, as do many of the peoples of today. But it does not follow that, because meteor showers and meteorite falls alarmed him, he attempted no recording of them; strikes of poisonous snakes and the sudden attacks of ferocious animals must have similarly terrified him, and yet drawings, paintings, and carvings of snakes and wild beasts were made by him in profusion.

That records of primitive man's attempts at the earliest depiction of meteoritical phenomena will be much rarer than those devoted to the animals and reptiles with which he fought, we must expect, for, even in paleolithic times, meteor showers and meteorite falls were no doubt infrequent, and still less frequently were they witnessed by men who had the ability, the facilities, and the opportunity to make faithful and enduring likenesses of them. Such rarity may ex-

plain the failure, so far, to discover meteoritical pictographs among the artistic records preserved from the earliest times, but it seems more likely to the writer that this failure may be due in part also to misinterpretation of the evidence available.

It is the purpose of the present paper to call attention to certain undoubtedly genuine meteoritical pictographs of moderate age; to suggest that a meteoritical significance properly can, and should, be associated with other known pictographs of much greater age; and, finally, to invite the collaboration of specialists in archeology, anthropology, and ethnology in exploring this promising and apparently neglected field. The importance, from the chronological standpoint, of the results achieved by the joint labors of astronomers and such collectors and collators of ancient *written* records of comets and meteors as Pingré and Biot, has long been recognized. Equal energy expended on the voluminous *pictographic* records of the past by coöperating archeologists, anthropologists, ethnologists, and meteoriticists might lead to even more notable additions to our chronology.

In this day, when studies of radioactive carbon in the bones of a long-dead artist may serve indirectly to date one of his portraits of a meteor shower, or when measures of the residual radioactivities induced in a meteorite by exposure to cosmic radiation may, reciprocally, serve to date the age in which a paleolithic artist painted the meteorite's fall, it is obvious that close coöperation between those who study ancient man and those who investigate early meteorite falls and meteor showers is likely to be mutually profitable.

§1. *Meteoritical Pictographs.*—The attention of the writer was called to the possibility of the existence of meteoritical pictographs by observing the facility with which the Navajos of the Four-Corners area of New Mexico, Arizona, Colorado, and Utah turned to pictographic means in describing the phenomena accompanying the fall of the meteorite of 1947 October 30, in that region. Lacking words with which to describe many features of this remarkable fall, they proved surprisingly adept at tracing in the dust, or on wooden, rock, or paper surfaces, pictures that told the story more effectively than their speech could have done. A copy of one such pictograph by tribesman Willie Begay is presented in Fig. 5. Stimulated by the observations made among the Navajos, an investigation of the literature was undertaken that disclosed that, from time immemorial, pictographs have been utilized by the American Indians and by many other races, not only for the transient purpose of description, but also for making permanent records of events regarded as important. One of the most comprehensive source books in this field of *picture-writing* is the monumental work of Colonel Garrick Mallery of the U. S. Bureau of Ethnology.[1] Figs. 1*a*, 1*b*; and 2*a*, 2*b*, copied from Mallery's book, show how a great meteorite fall occurring in the winter of 1821-22, and the spectacular Leonid meteor shower of 1833 November 13, were permanently recorded by historians of the Dakota tribe in the *Winter Counts*, by means of which they established a chronological system. These Winter Counts were pictographic records, *e.g.*, paintings on the tanned inner skin of a buffalo robe, of the *year-characters* arranged on a spiral or similar curve, whereby the Dakotas established a continuous designation of the years without having to resort to some scheme involving assignment of consecutive numerals to them.

Scientific records of the actual fall of a meteorite in the winter of 1821-22 seem to be lacking. As Mallery remarks, "There were not many correspondents

FIG. 1*a*
Meteorite Fall, Dakota Winter Count, 1821-*22*: "Star-passed-by-with-loud-noise winter"

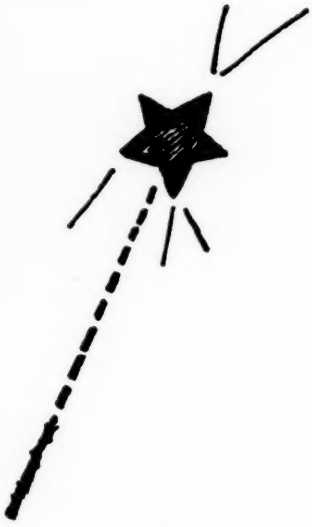

FIG. 1*b*
Meteorite Fall, Dakota Winter Count, 1821-*22*: "One-star-made-a-great-noise winter"

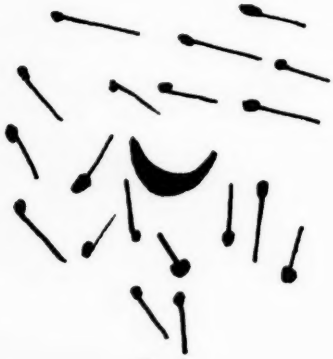

FIG. 2*a*
Leonid Shower (1833 Nov. 13), Dakota Winter Count, 1833-34: "Many stars fell . . . Dakotas much terrified"

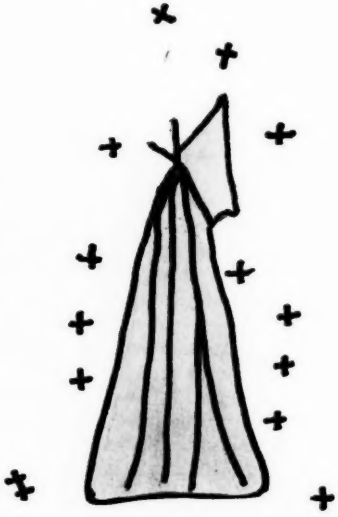

FIG. 2*b*
Leonid Shower (1833 Nov. 13), Dakota Winter Count, 1833-34: "Storm-of-stars winter"

of scientific institutions in the Upper Missouri region at the date mentioned." Furthermore, because of the enormous territory ranged over by the various tribes or bands of the great Dakota Nation, it is difficult to decide which one of several recovered meteorites of *recent* fall found in Dakota-land in the later 1800's is most likely to have been associated with the fall observed in 1821-22. The Fort Pierre, South Dakota (coördinate number = 1003,344), and the Iron Creek, Alberta, Canada (C.N. = 1115,530:), octahedrites would seem to deserve careful consideration in this connection. As regards the Leonid shower of 1833, however, a wealth of historical and descriptive material is preserved in scientific journals and elsewhere. Intercomparison of the white- and red-men's records of this meteor shower shows that both received the same impression of a veritable snowstorm of stars, descending into the very faces of the observers. Furthermore, the printed testimony justifies the Dakotas in representing the individual Leonid paths as luminous hair-lines ending in bright bursts or flares (light curves of Type II), similar to those observed for about 15% of the brighter ν Draconid meteors of 1946 October 9. The crescent in Fig. 2*a may* have been intended to represent the young Moon, which set about an hour after the Sun in the early evening of 1833 November 12. If this interpretation is indeed correct, then the association of this crescent with the Leonids indicates that in Dakota-land, as at certain other places in the United States, the forerunners of the great shower were observed in sufficient numbers to attract attention even before moonset. It is more likely, however, that this crescent was intended to represent an extremely bright, long-enduring Leonid train. Such brilliant, long-enduring trains attracted universal attention among white observers and led to such printed descriptions as the following: "The Hon. Calvin Pease informs me he discovered it at 4 o'clock; . . . it was then very brilliant, in the form of a *pruning hook* . . . I first saw it at 5 o'clock, when it resembled a *new Moon*, 2 or 3 hours high, shining thru a cloud. . ."

In addition to the *portraitures* of meteorite falls and meteor showers, painted by the Amerinds, meteoritical pictographs of a *conventionalized* form have been discovered in the records left by the ancient Mexicans, who were accustomed to use for meteor falls symbols reminiscent of those employed by the Europeans of the Middle Ages for representing comets. In plates 29 and 30 of the first volume of Lord Kingsborough's compendious work on Mexican antiquities,[2] there is reproduced one device-figure containing a circle inclosing an 8-pointed star with black spiraling plumes trailing from it (see Fig. 3), and another device-figure showing a serpent darting out of a bowl of stars (see Fig. 4).

In the codex *Telleriano Remensis*,[3] the first of these symbols is referred to as a smoking star, and the second as a serpent descending from the sky. G. Mallery believes that the first symbol represents a meteor that fell in 1534 (the year that Don Antonio de Mendoça became Viceroy of New Spain, according to the codex quoted), and that the second symbol represents a meteor that fell in 1529 (the year that Nuño de Guzman set out to conquer the Province of Yalisco, according to the same codex). Doubtless a careful search of the voluminous records left by the ancient Mexicans would disclose many other meteoritical pictographs.

§2. *Picture-Writing of Possible Meteoritical Significance.*—The examples of the preceding section show that meteoritical pictographs may be either portrai-

FIG. 3
Smoking Star of 1534 in Mexico

FIG. 4
Serpent Descending from the Sky in 1529 in Mexico

FIG. 5
Meteorite Fall of 1947 Oct. 30

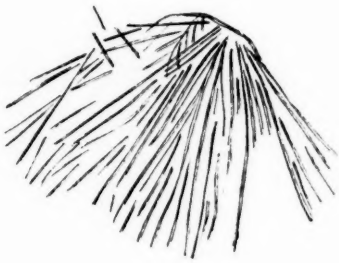

FIG. 6
Radiate-Structure (Meteor-Shower?) Cavern at Altamira, Spain

tures or conventionalized forms. If, with this fact in mind, one examines such pictographic collections as those published by Kingsborough and Mallery, a considerable number of drawings and paintings will be noted that appear to have meteoritical significance. Furthermore, *petroglyphs*, or rock carvings, believed to be of even greater antiquity than the Mexican and Amerind pictographs, also seem to have such significance. Thus a petroglyph found near San Marcos

Pass, California, pictures[4] 2 star-like figures joined by a trail, suggesting the path of a meteor from one position to another in the sky; another rock carving in Kansas shows[5] a 5-pointed star surrounded by a cloud; and a petroglyph at Ojo de Benado, New Mexico, depicts[6] what appears to be a crescent Moon crossed by a hair-line path with a terminal burst, closely resembling Dakota pictographs of typical bright Leonid meteors.

Finally, altho published collections of late paleolithic pictographs (devoted as they are primarily to the more remarkable of innumerable animal portraitures) can scarcely be regarded as giving a typical sample of the work of the artists of that period, nevertheless they contain many forms suggestive of meteors and meteorites. One type in particular seems worthy of consideration in this connection, *viz.*, the category of so-called *radiate structures* (*figures rayonnantes*) found in the cavern at Altamira, Spain, and studied with such care by Breuil and Cartailhac,[7] who point out that, in spite of their best efforts, the meaning of these drawings is not understood. All kinds of interpretations of these figures have been given, ranging from "a bit of reed-grass"[8] to a "magic weapon."[9] In the writer's opinion, some of the "sheaves of rays" at Altamira are attempted portraitures of auroral wreathes (*i.e.*, incomplete auroral crowns),[10] but others, like the one shown in Fig. 6, are attempted portrayals of showers of shooting-stars in which a few curved and otherwise abnormal paths and several non-conforming meteors also were seen. The fact that the represented meteors are not shown shooting outward in *all* directions from the radiant is not fatal to this interpretation, for a similar, altho somewhat less restrictive, limitation in directions of departure from the radiant is shown, *e.g.*, in the Greenwich drawing of the Leonid shower of 1866 November 13, reproduced in Chambers' *Astronomy*.[11] Perhaps a more puzzling feature is the remarkably small value of η, the angular distance of the point of appearance from the radiant, exhibited by some of the longer-pathed paleolithic meteors that seem to start very near the radiant.

It is natural to ask whether even an informed guess can be made as to the identity of the shower that may have been responsible for the Altamira pictograph. In this connection, it is of interest to note that, twice within the period during which it is believed the artists of the Reindeer Age were active, there were long intervals of time when the radiant of the annual Lyrid shower was near the north celestial pole, and hence when, as seen from the latitude of the Pyrenees Mountains, it occupied a nearly stationary position, high in the northern sky, very favorably placed for observation from the old entrance of the cavern at Altamira, which, according to Cartailhac and Breuil, opened toward the north at the top of a hill.[12] As there is excellent evidence that earlier, richer showers of the Lyrids can be traced back into the past for more than 2500 years,[13] it is not inconceivable that spectacular paleolithic returns of this perennial shower inspired such portraitures as the Altamira pictograph.

References and Note

[1] Garrick Mallery, *Annual Report of the Bureau of Ethnology*, **10**, 25-777, 1893.
[2] Edward K. Kingsborough, *Antiquities of Mexico*, 9 vols., London, 1831-48.
[3] Kingsborough, *loc. cit.*, **6**, p. 148.
[4] Mallery, *loc. cit.*, p. 62, Fig. 21.
[5] Mallery, *loc. cit.*, p. 81, Fig. 44.
[6] Mallery, *loc. cit.*, p. 97, Fig. 58.

[7] E. Cartailhac and L'Abbé H. Breuil, *L'Anthropologie*, **15**, 625-44, 1904.

[8] Cartailhac and Breuil, *loc. cit.*, p. 637.

[9] Max Raphael, *Prehistoric Cave Paintings*, p. 78, New York, 1945.

[10] A note on this suggested interpretation will be published elsewhere.

[11] George F. Chambers, *Handbook of Descriptive Astronomy*, 3rd Ed., p. 805, Oxford, 1877.

[12] Cartailhac and Breuil, *loc. cit.*, p. 626.

[13] E. Biot, *Catalogue Général des Étoiles Filantes et des Autres Météores Observés en Chine pendant 24 Siècles, Mémoires des Savants Étrangers*, **10**, 74, Paris, 1841.

The Energy of the Podkamennaya Tunguska, Siberia, Meteoritic Fall (∓1019,609)

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ABSTRACT

This note points out that, in case F. J. W. Whipple's estimate of the energy expended by the Podkamennaya Tunguska, Siberia, meteorite on the atmosphere is accepted, the mass of this meteorite, assumed to be terrene in composition, must have been of the order of 10^7 metric tons, if its velocity was 10 km./sec., and of the order of 10^5 metric tons, even if its velocity was 100 km./sec. The enormity of these terrene masses, coupled with the failure of exhaustive search to recover any fragment whatever of this fall, is held to support the hypothesis that the Podkamennaya Tunguska meteorite was contraterrene in nature.

Several cogent arguments in favor of the existence of contraterrene meteorites have already been advanced,[1] and certain experimental evidence, as yet unpublished, supporting the hypothesis of the existence of such meteorites, has been obtained at the University of New Mexico. The purpose of the present note is to call attention to additional observational evidence favorable to the contraterrene hypothesis.

According to F. J. W. Whipple,[2] about 5,000 times as much energy, E_a, was expended by the Podkamennaya Tunguska, Yeniseisk, Siberia, meteorite (C.N. = ∓1019,609) in the production of air waves as was transmitted to the solid body of the Earth. Shortly after Whipple published this estimate of the energy that went into the air, I. S. Astapowitsch made a very careful determination of the energy that went into the ground. If we denote the latter energy by E_e, then, from Astapowitsch's evaluation of the energy of the earthquake produced by this fall, we have E_e approximately equal to 10^{21} ergs.[3] Accepting Whipple's estimate of E_a in terms of E_e, we find that the total energy E ($> E_a + E_e$), released by the fall, was certainly not less than 5×10^{24} ergs. Hence, if the Podkamennaya Tunguska meteorite was terrene, and had a velocity of 10 km./sec. (100 km./sec.), its mass, m, was not less than 10^{18} g (10^{11} g), *i.e.*, 10^7 (10^5) metric tons.

The enormity of the masses just computed, and the complete failure of exhaustive ground searches to recover a single fragment of meteoritic material ascribable with certainty to the Podkamennaya Tunguska fall,[4] seem to me to be rather compelling evidence that the vast energy released by this fall did not come solely from the transformation of the kinetic energy of motion of the

meteorite; rather, that the principal source of the huge amount of energy released is to be sought in the mutual annihilation of a contraterrene meteoritic mass and terrene material.

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[2] Whipple, F. J. W., *Quar. Jour. Roy. Meteorol. Soc.*, **56**, 287-304, 1930, and *Geog. Jour.*, **81**, 245, 1933.

[3] Astapowitsch, I. S. (translation by L. La Paz & G. Wiens), *C. S. R. M.*, **2**, 203-26; *P. A.*, **48**, 433-43, 493-506, 1940.

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An Appeal for the Support of Meteoritical Research at the Institute for Nuclear Studies

All members of the Meteoritical Society must have read with keen pleasure the announcement that the 1947 $1,000 prize of the American Association for the Advancement of Science, for "a notable contribution to science," had been awarded to Dr. Harrison S. Brown, of the Institute for Nuclear Studies of the University of Chicago, for his paper on "Elements in Meteorites and the Earth's Origin."* Dr. Brown and his associates are now embarked on a program to determine the statistical distribution of gallium in meteoritic matter, this element being apparently somewhat more abundant in meteorites than in terrestrial rocks. They employ a special analytical technique involving radioactivities generated in the neutron pile at the Institute for Nuclear Studies. In connection with this work, Dr. Brown has need for as many samples, of approximately 10 grams' weight each, of different meteorites, as can be secured. Because of the fundamental importance of the meteoritical research that is being carried on at the Institute for Nuclear Studies, not only from the cosmological standpoint, but also as regards such eminently meteoritical problems as the development of dependable criteria for the identification of meteorites, it is felt that many members of the Meteoritical Society will wish to join the Institute of Meteoritics of the University of New Mexico in donating small samples of meteorites for Dr. Brown's experimental work. It is suggested that all persons wishing to contribute meteoritic samples for this purpose send a list of the meteorites from which they can most conveniently spare pieces of approximately 10 grams' weight to:

Dr. Harrison S. Brown, Institute for Nuclear Studies,
The University of Chicago, Chicago 37, Illinois.

LINCOLN LA PAZ
Institute of Meteoritics, University of New Mexico, Albuquerque

A Note by the President of the Society in Support of the Foregoing Appeal

This is an opportunity for the members of the Meteoritical Society to support a research being carried on by a thoroly up-to-date method, which has already yielded highly important results. In reading the papers published by Dr. Brown, I have been impressed by the able manner in which his experiments were performed and deductions were made from them. I hope that many offers of

*V., *e.g.*, the note on this subject in the May instalment of *C. M. S.*

material will be made by members in a position to furnish specimens.

ARTHUR S. KING

Mount Wilson Observatory, Pasadena 4, California

President of the Society: ARTHUR S. KING, Mount Wilson Observatory, Pasadena 4, California

Secretary of the Society: OSCAR E. MONNIG, 1010 Morningside Drive, Fort Worth 3, Texas

The Amateur Astronomer and Meteoritics*

The study of meteors, I believe, offers the most and varied opportunities for the amateur to aid science. It is hoped that by pointing out some of these opportunities, I may be able to interest persons in investigating further and perhaps becoming meteor observers, for more active observers is the great need in New England. Secondly, I hope we can effect some kind of organized effort in our work thereby immensely increasing its value. Not only would we get more pleasure from our hobby but also strengthen our scientific standing. It may be that amateur astronomy in the near future will tend to become merely arm-chair acquiring of knowledge, or like stamp collecting or fan clubs where we only collect, acclaim, and admire. Just as industrial research is bringing about the end of the independent inventor so does modern organized research in pure science threaten the standing of the amateur as to his scientific value. We must therefore apply a searching mind, coordinate our efforts, and take advantage of modern techniques in our work. Variable star observers have begun to do so by using photomultipliers.

Meteor observing is generally presented as the simplest activity for the amateur. I feel that it is the most difficult. It requires considerable physical stamina, patience, and care, but those who become enthusiastic observers feel it is all interesting trouble and are sure in the knowledge that they are helping collect data which will have a bearing on some of the most profound problems of science.

In general we can state that no matter how much has been done to date in studying any particular field in meteors, we can add to that knowledge by further study. Even simple counting of meteor rates, if continued regularly by many observers, would result in new data especially bearing upon those like the Hoffmeister-Olivier investigation into the possibility of extra-solar meteors, to mention but one of a dozen uses of such observations.

We have a great opportunity to help educate the public in the facts about fireballs and bring about the end of such reportorial exhibitions as the flying saucer stories. We would gain tremendously in getting good reports on fireballs by helping collect them, interviewing observers and conducting immediate searches for possible meteorites. Persons from Massachusetts please note that no meteorite has been found in that state. New England has countless miles of field stones piled in walls along cleared fields. Using a modern mine detector along these walls in a systematic search would certainly sooner or later bring to light some meteorites.

The plotting of meteors has been the chief activity of observers and one of greatest value. It would be a long story to point out at this time all the various

*Adapted from some remarks on meteors made at the first New England Regional Convention of the Astronomers League.

data which are obtained from them or, equally important, data which could be obtained if such observing were conducted by many observers who planned and coordinated their work. Several years ago our New Haven group cooperated with Vassar, Mt. Holyoke, and Smith Colleges in plotting for heights during showers. These observations were statistically examined and published. We amateurs here were amazed at the amount of data obtained and by the promise that such observations held if they were continued systematically over long periods.

Although naked-eye observing is highly important we should not be satisfied with such work alone. I have made it a point never to observe without binoculars and camera handy. A regular observer is bound to see a fireball and train every so often and binocular observations with possibly a photo make an observation of far greater value. There is a great field in regular photographic patrolling for meteors though such work is a matter of patience and luck. One never knows but that some one photo will aid materially in the study of these bodies. Photographing meteor spectra entails additional difficulties but is of proportionately greater value. Such programs mean some expense, but I always like to point out that amateur astronomy is about the most economical of hobbies. Any radio ham or home workshop hobbyist spends more. Incidently we should try to enlist the aid of such hobbyists. For instance, radio hams to establish communication between cooperating groups and telescope makers in constructing mountings and equipment for photography would be welcome.

Attention should be brought to the opportunities in observing telescopic meteors. Besides the reporting of casual meteors, definite programs can be laid out. Two such programs would be, first, the placing of two or more telescopes at such distances apart and inclined at such angles to each other that their fields of views intersect at the same height in the atmosphere, secondly the combined visual and binocular observing by two groups to determine the heights of the faint beginning parts of meteor trails. These are but two of many programs.

Professor Olivier has more than once stated that he would be glad to outline special programs to really serious amateurs and to help in preparing papers. Incidently papers do not necessarily have to be technical. For instance, I believe I could prepare one on how to keep warm and comfortable while observing meteors in winter. There are many tricks to that. About twenty years ago the Texas Observers conducted a sort of conclave by correspondence on hints and methods of plotting meteors, bringing to light many interesting and useful hints. I suggest that it is time to conduct another and present it as a paper for the benefit of observers, old and new.

The truly spirited and serious amateur can even undertake original projects. Two suggest themselves to me at this time. One could attempt to photograph a meteor with cameras revolving on a mounting so that a bright meteor travelling at right angles to the cameras' motion would leave a trail showing to advantage the progress and phenomena of the hot gases in its wake. Careful choice of optimum direction and speed of camera travel, relative to possible meteor paths as from a shower, would have to be made. The same could be accomplished by a stationary camera with a rotating plate or conversely with an oscillating lens. A second field is the investigation of direct static originating in the meteor's flight. All the work on meteoric electronics seems to be concentrated in the field of radar and the "whistles" and "bursts." Investigating the direct static would mean some rather technical and expensive equipment and much experimentation but surely the interest and adventure of such a project will lure someone. Actually

some amateurs are engaged in "whistle" and "burst" investigation and I believe that even radar is not beyond our grasp and ability. A recent British development seems to simplify radar equipment so that it is nothing more than an overgrown super-regenerative receiver. Some one may well emulate Mr. Grote Reber of cosmic and solar hiss fame and who started as an amateur. We need serious and sporting amateurs for projects such as the few I have sketchily mentioned and I am hoping that what has been said will help bring to light such people.

VINCENT ANYZESKI.

1574 High Street, East Haven, Connecticut.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Current Notes on AAVSO Variables: In order to keep observers informed on the current activities of some of the stars which are being observed, the following facts are cited.

R Andromedae, 001838. The recent maximum, around JD 2432525 (Dec., 1947), attained the sixth magnitude, and the star is now steadily decreasing to minimum, probably to fainter than magnitude 14.

RR Sculptoris, 002438 b. This star appears to show no evidence of variation, having remained nearly constant at magnitude 12.7. There seems to be little reason for observing the star further.

S Cassiopeiae, 011272. The extra-long long-period variable is due at maximum, about magnitude 9.0, in July next, after an interval of 610 days since the last observed maximum in December, 1946. The increase to maximum should start early in June and should be carefully observed.

S *Aurigae,* 052034. Whereas for some years back S Aurigae appeared not to follow its usual course as a regular long-period variable, recent observations indicate that it has now become normal in its variability.

SU Tauri, 054319. This R Coronae Borealis-type variable remains at maximum, between magnitude 9 and 10.

RS Aurigae, 055646 a. A period of 172 days is further confirmed, but its nearby comparison SV Aurigae variable shows no regularity in form of light curve.

SS Aurigae, 060547. For this well known SS Cygni-type variable, a broad maximum occurred late in March, magnitude 10.8, some 90 days following the last previously observed broad maximum.

SW Geminorum, 065326. A minimum of this star took place about JD 2432360 (April 18). A period of 680 days thus appears to be confirmed.

U Geminorum, 074922. A broad type maximum, well observed on the rise as well as throughout the whole maximum, occurred early in March, about 135 days after the previously observed broad type maximum.

Z Camelopardalis, 081473. Since late in March this rather unique variable appears to have again settled into the state of small variation in brightness, about

halfway between normal maximum and minimum magnitude. The star should be observed closely to insure completeness of light curves.

IW Carinae, 094263. Observations received from South Africa in recent months seem to indicate a periodicity of about 70 days, with an amplitude of about 1.25 magnitudes.

R Leonis, 094211. This well known long-period variable reached maximum, magnitude 5.7, about April 10.

R Centauri, 140959. This double maximum type long-period variable attained a deep minimum, magnitude 12.0, early in April.

S Apodis, 145971. Observations made as late as March 10 indicate that this far southern R Coronae Borealis-type variable was still faint, magnitude 14.0. The star has been below normal maximum brightness for more than a year.

R Coronae Borealis, 154428. This star is still at normal maximum, magnitude 6.0, where it has been for the past 400 days.

T Coronae Borealis, 155526. The recurring nova of 1866 is at normal minimum brightness. If the present observed magnitude of 10 indicates the "M" star companion, then "T" itself may be appreciably fainter.

RS Ophiuchi, 174406. This other recurring nova—with three maxima already experienced in the last half century—continues to fluctuate in brightness between the tenth and twelfth magnitude, having attained the brighter magnitude in September, 1947. The star is now gradually becoming fainter.

R Scuti, 184205. For this so-called RV Tauri-type variable, a shallow minimum, magnitude 6.2, is indicated early in April.

RY Sagittarii, 191033. This southern R Coronae Borealis-type variable, after remaining at or near minimum for more than a year, is now well on the increase to maximum brightness, having risen from magnitude 12.4 late in February to 9.7 on May 1. Late in 1947 the star was reported as of magnitude 13.4.

R Cygni, 193449. This interesting long-period variable reached maximum, magnitude 6.7, in February, the brilliance at that time being more than two magnitudes greater than that observed in 1946-47. With an observed minimum at 14, this shows an increase of more than seven magnitudes.

Chi Cygni, 194632. This star, one of the first of the long-period variables to be discovered, is again on the increase to maximum, due to be reached early in July. With the possibility of a "still-stand" occurring soon, the star should be carefully watched.

T Cephei, 210868. This somewhat anomalous long-period variable was at its high maximum, magnitude 6.0, in April, with strong evidence of the usual "still-stand" just before maximum light was attained.

SS Cygni, 213843. An exceptionally broad maximum (No. 364) was observed in March, following the short, narrow maximum observed early in February.

Observations contributed in April, 1948: A total of 3,598 observations was contributed by 54 observers, as follows.

Observer	No. Obs.	No. Ests.	Observer	No. Obs.	No. Ests.
Adamopoulos	7	7	Bappu, M. K. V.	30	37
Ahnert, P.	40	666	Blunck	12	13
Alder	2	4	Bogard	33	75
Ancarani	27	55	Cain	9	9
Bappu, M. K.	28	50	Chandra	109	168

Observer	No. Obs.	No. Ests.	Observer	No. Obs.	No. Ests.
Chassapis	17	19	Parks	24	27
Cilley	25	54	Pearcy	46	67
Cragg	55	57	Peltier	97	143
Darnell	5	38	Penhallow	8	13
Debono	3	12	Plybon	4	12
Estremadoyro	12	22	Renner	69	69
Fernald	258	475	Rich	5	8
Focas	13	18	Rosebrugh	13	73
Ford	6	6	Seagroves	7	14
Greenley	18	21	Stein	1	2
Hartmann	105	110	Svolopoulos	8	8
Hiett	10	28	Taboada	89	101
Howarth	15	15	Tarbell	3	10
Kelly	11	11	Thomas	3	3
Kirchhoff	16	50	Tifft	33	55
Kitley	20	27	Wade	4	4
de Kock	105	470	Waldmann	19	66
LeVaux	31	75	Webb	29	29
Luft	4	4	Weitzenhoffer	3	6
Miller	10	12	Wells	2	2
Nadeau	22	38	Werntz	6	19
Oravec	63	200	—		—
Parker	20	20	54	totals	3598

May 15, 1948.

Comet Notes

By DANIEL L. HARRIS III

Comet activity has died down during the past month and at the present time there are only two comets visible with modest telescopes and both are getting fainter rapidly.

COMET MRKOS (1948 *d*) is visible in the northern sky as is COMET BESTER (1947 *k*). The motion of comet 1948 *d* takes it quite near the north polar regions as seen in the following ephemeris by Dr. Guth of Prague (UAIC 1147).

		α h m	δ ° ′
June	2	18 4.5	+79 10
	10	16 58.6	82 32
	18	15 4.2	84 8
	26	13 7.2	83 41

Cunningham's ephemeris for COMET BESTER (1947 *k*) given below predicts the comet to be between the 10th and 11th magnitude during June.

		α h m	δ ° ′
June	2	10 28.6	+50 31
	10	10 28.0	47 51
	18	10 29.6	45 37
	26	10 32.4	43 44

So far this year there have only been three new comets, COMET KEUSKAMP (1948 *c*) not having been confirmed. Periodic COMET FORBES (1929 II) has not been recovered as yet, although it is predicted to be 13.9 magnitude and should be easily found with a large telescope. Other periodic comets listed in the *B. A. A. Handbook* for 1948 are

COMET WHIPPLE (1923 IV) recovered on 1947 June 21 by Jeffers at Lick,
COMET SCHWASSMANN-WACHMANN (2) (1929 I) recovered on 1947 October 20 by Van Biesbroeck,
COMET NEUJMIN (2) (1916 II),
COMET NEUJMIN (1) (1913 III),

and the two comets which are observable throughout their whole orbit, COMET SCHWASSMANN-WACHMANN (1) (1925 II) and COMET OTERMA (1942 VII).

None of the periodic comets is expected to become brighter than 13th magnitude.

Yerkes Observatory, Williams Bay, Wisconsin, 10 May 1948.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editor may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

A Possible Explanation of an Exploding Universe

The astronomers have observed that the lines of the spectrum of the light from the galaxies is shifted toward the red end of the spectrum. The farther away the galaxies the more pronounced is this shift, indicating a velocity of recession of thousands of miles a second for the most remote. As the shift of the spectrum lines toward the longer wave lengths signifies that the source of light is receding, it is evident that the gaps between the galaxies are widening—that the galaxies are diverging from one another—as if the universe were being driven asunder.

To the knowledge of the author (not a professional astronomer), the following explanation of the cause of this perplexing, most significant phenomenon has not yet been advanced. Assumed in this explanation is that:

1. Our universe is of finite, limited dimension.
2. Our universe is a rotating system of unknown billions of galaxies in which the galaxies have rotational and rectilinear motion around the gravitational center of the universe.

If throughout our universe its composing galaxies are luminous as is the Milky Way then it is very evident that during the astronomical eons an enormous amount of matter (estimated at 4,000,000 tons a second on our sun—far greater on hotter stars) has been and is still disintegrating into radiant energy and dissipating into the Space of the Great All—away from our universe. The resulting, steadily diminishing attraction of the universe (its holding together force) causes the galaxies to fly away from the center of gravity of the universe in ever widening orbits, diverging from the orbits of the other galaxies. Observed on earth through the spectroscope it looks as if the galaxies are speeding into distance, the most remote fastest—diverging from one another, as fragments of an explosion diverge from others during their flights. In other words, it simulates an exploding universe.

The dispersive action (*i.e.*, loss of gravity) due to the loss of matter as

radiant energy naturally also occurs in the galaxies themselves and it may be the chief cause of their acquiring the spiral and other shapes. But its effect in the galaxies is totally obscured by the diverse proper motions of the stars.

An assumption that most of the radiant energy is incident on the matter in the universe, absorbed by it, and that, therefore, the total mass does not get less, or very little so, does not hold. The galaxies are sieves in which the suns on the average are ten million times their diameter apart. Nor does the sparse cosmic dust and meteoric matter absorb much. Altogether only a minute fraction of the total radiant energy is thus absorbed.

The magnitude of the universe is unknown. It is a matter of speculation. It may comprise from ten to one thousand billion galaxies. It may be hotter in some sections and it may be cooler in others. It may be of various density. But the bigger the universe the greater is its holding together attraction—and, within limits, its dispersing action caused by the change of matter into radiation. The magnitude of the shift of the spectrum lines of the most remote observable galaxies might indicate that our Milky Way is situated in a rather outer zone of the universe—unless the age of the universe, and hence its dispersing action, is immensely greater than the age of a luminous sun—all unknown factors.

SUMMARY

The radiant energy of the suns is the product of atomic disintegration of matter—lost into space. The mass of the universe is thus decreasing and its gravitational force is diminishing, causing the galaxies to fly away from its center. Thus the size of the universe is increasing.

The mass of the universe will decrease until all fissionable atomic matter has been expended.

Besides the point, merely speculative and of limited importance: It may be that in the Space of the Great All the universes are so far apart that their farthest reaching phenomena vanish long before they reach another universe and thus cannot affect any other—that they are closed systems, unaffected by any other, unobservable—each as if alone in the Great All.

All that is enchantingly elucidated in a not yet published scientific novel "The Triumph of Reason" written by the author.

HENRY EHRENBERG, D.Sc.

34 Stephens Way, Berkeley 5, California.

General Notes

Subscribers will remember that there is no issue of this magazine in July. The editor will attend the meeting of the American Astronomical Society in Pasadena and the August issue, which will contain a report of the meeting, will be delayed until his return. It will probably appear about September 1 instead of August 1 as usual.

Dr. P. Swings, Professor of Astrophysics at the University of Liége, Belgium, and Research Associate of the Yerkes and McDonald Observatories, has been awarded the Francqui prize—the highest scientific distinction in Belgium.

Dr. Martin Schwarzschild, of the Princeton University Observatory, spoke before the Geophysical Seminar of the University of California, Los Angeles, on May 25, 1948, on "The Solar Rotation."

Dr. Jesse L. Greenstein, for some years a member of the staff of the Yerkes Observatory, has been appointed Associate Professor of Astrophysics at the California Institute of Technology, Pasadena, California. He will take up his duties there on July 1.

The Rittenhouse Astronomical Society, of Philadelphia, held its monthly meeting on May 21, 1948, in Randal Morgan Physics Laoratory, University of Pennsylvania. The speaker, Dr. N. E. Wagman of the Allegheny Observatory, University of Pittsburgh, used as the subject of his address "Life in the Universe."

Astronomical Meeting

A joint meeting of the American Astronomical Society and the Astronomical Society of the Pacific will be held in Pasadena, California, June 28-July 1, 1948, at the invitation of the Mount Wilson Observatory and the California Institute of Technology. It will be the seventy-ninth meeting of the American Astronomical Society. An afternoon and evening on Mount Wilson is planned for Tuesday, June 29. The program on the mountain will include a dinner and evening observations with a 100-inch telescope. An all-day trip to Palomar Mountain is planned for Thursday, July 1, with a symposium devoted to the 200-inch telescope.

Because of limitations in space and transportation facilities, the trips to Mount Wilson and Palomar Mountain will be open only to members of the two Societies and their immediate families and to invited guests.

Arrangements have been made to house attending members in the dormitories at the California Institute of Technology and to have most of the meals and meetings on the campus. Because of the arrangement of the rooms it will probably be necessary to house the men and women on separate floors. A price of $1.50 per night for room and $3.00 per day for meals has been quoted, subject to later revision.

Dedication of the Palomar Observatory

The Office of Public Relations of the California Institute of Technology has announced that the Palomar Observatory and its 200-inch telescope will be officially dedicated on June 3. The ceremony will be held at 2 P.M. in the observatory on Palomar Mountain.

It is expected that there will be some 800 to 1,000 invited guests and newsmen in attendance. The ceremony will not be open to the general public because there is a limit to the number of people that can be accommodated in the observatory.

The program will be presided over by Mr. James R. Page, chairman of the Board of Trustees of the California Institute of Technology. Short speeches will be made by the following persons: Dr. Raymond B. Fosdick, President of the Rockefeller Foundation; Dr. Max Mason, Chairman of the Caltech Observatory Council which designed and directed the Palomar project; Dr. Lee A. DuBridge, President of Caltech who will deliver the dedication speech; Dr. Vannevar Bush, President of the Carnegie Institution of Washington, D. C. (The Carnegie Institution and Caltech will operate jointly both Palomar and the Mt. Wilson Observatories); and Dr. Ira S. Bowen, Director of the Palomar and Mt. Wilson Observatories. Following his address, Dr. Bowen will also explain and demonstrate operation of the 200-inch telescope.

The Milwaukee Convention of the Astronomical League

The plans for the annual convention of the Astronomical League in Milwaukee are taking final form. Registration (fee $1) will begin on Saturday morning, July 3, at 9:00 A.M. in Wunder Dormitory of Concordia College. The first general session will get under way at 10:00 with roll call and reports from member organizations. These reports will be followed by a short session for papers and then lunch at 12:30 in the dormitory dining room.

The afternoon program will start at 2:00 p.m. with a short session for papers which will be followed at 3:00 p.m. with an address by Dr. Jack T. Wilson, Physicist of Allis Chalmers Company on "Recent Investigations of the Sun's Radiation."

The first business meeting will be called at 4:00 P.M. and will be followed by an early supper at 5:30 so that all will be ready to leave by 6:00 for an evening at the Milwaukee Astronomical Society Observatory.

Sunday morning the program resumes at 9:30 A.M. with a session for papers and a report on his Burma eclipse experience by our president, Ed Halbach. This will be followed by a group photograph, and banquet at 12:30. We hope that our vice president, Charles Federer, will be back from Palomar Mountain in time to report on the Society meeting there for us at the banquet.

Sunday afternoon at 2:00 P.M. we are tentatively planning section meetings on instruments, observing, etc., with lots of time for discussion so we trust you will come prepared to speak your mind. This will be followed by a short business meeting and an early supper so that everyone will be ready to leave for Yerkes Observatory at 6:00 P.M.

Arrangements have been made to spend Sunday evening at the Yerkes Observatory (largest refracting telescope in the world). A member of the Yerkes staff will present the recent planetary investigation made by Dr. Kuiper at McDonald Observatory in Texas.

Monday morning there will be a short paper on "Astronomy in South America" by Mr. L. E. Peterson. This paper will be followed by the main business meeting of the convention. At this time plans will be made for the 1949 convention, officers will be elected for 1949, reports of the section meetings will be made, resolutions (if any) will be passed, etc., after which the convention will be adjourned.

The convention is to be held at Concordia College which is located in Milwaukee about two and one half miles west of the center of the downtown area. The campus is bounded by State Street on the North, Thirty-third Street on the West, Kilbourn Avenue (one block south of State) on the South, and Thirty-first Street on the East. The dormitory at which registration will be held and where visitors will be housed is located at 3215 West State Street. Meals and lodgings at the dormitory will cost $5 per day and reservations should be made with Roy L. Dodd, 7918 Milwaukee Avenue, Milwaukee 13, Wisconsin. Those who prefer to stay at hotels will be able to obtain their meals at the dormitory with breakfast at seventy-five cents, noon meal $1.50, and evening meal $1.00.

If you have any equipment you wish to display at the convention, please get in touch with Mr. Roy R. Lee, 3168 South 97th Street, Milwaukee 14, Wisconsin. He will instruct you as to when and where to ship the equipment.